Journal

of

THE ROYAL AERONAUTICAL SOCIETY

DECEMBER 1959

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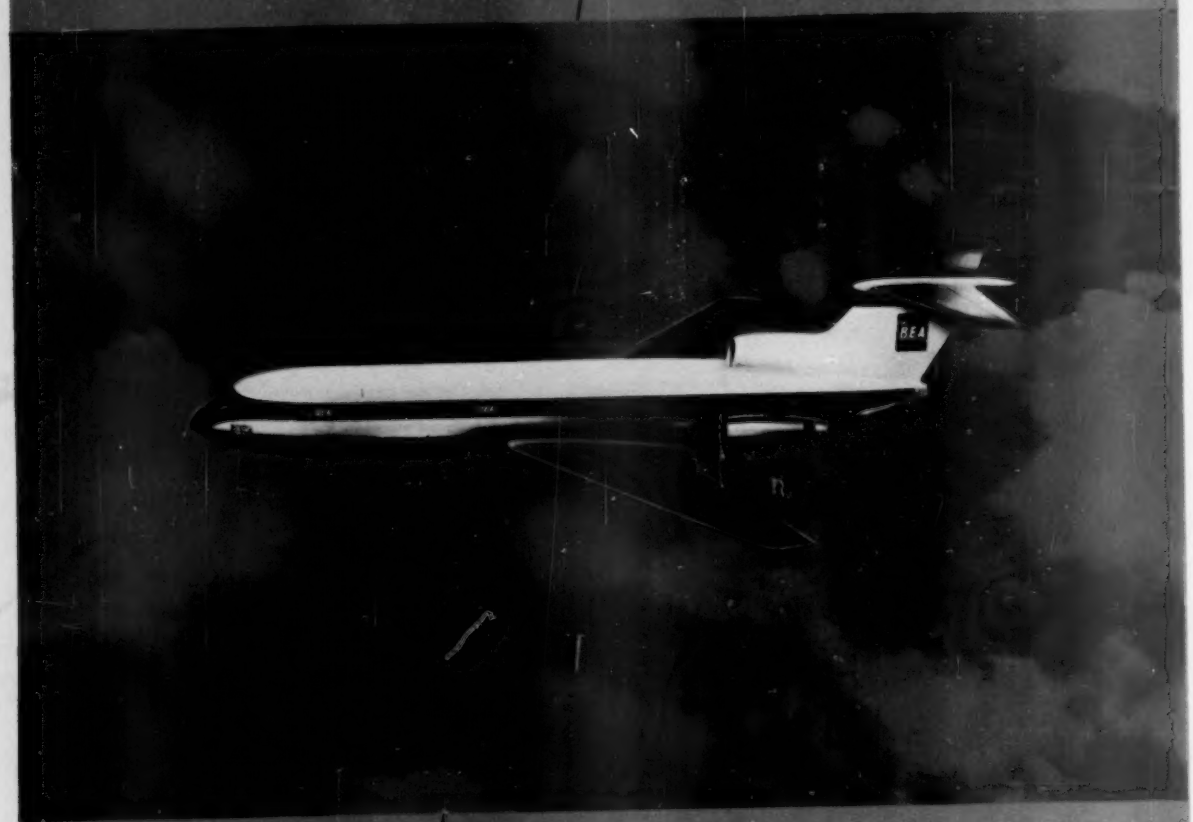

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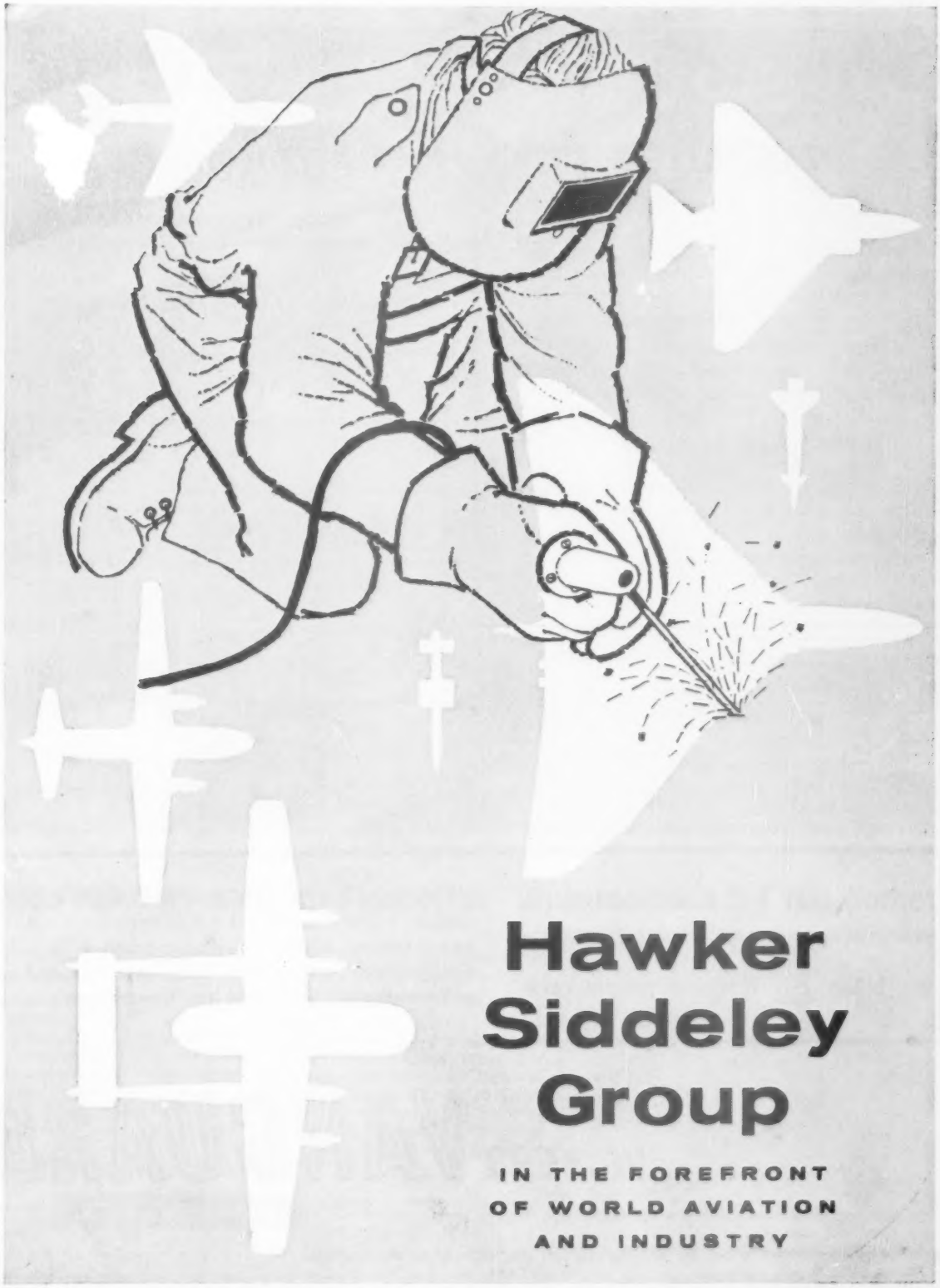
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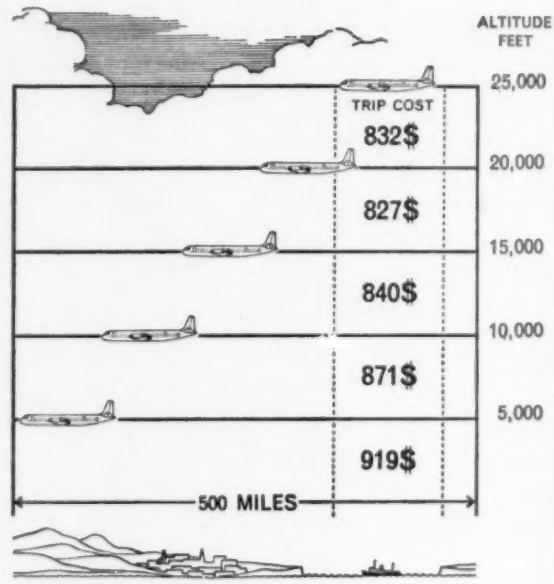

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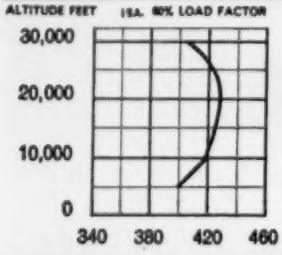

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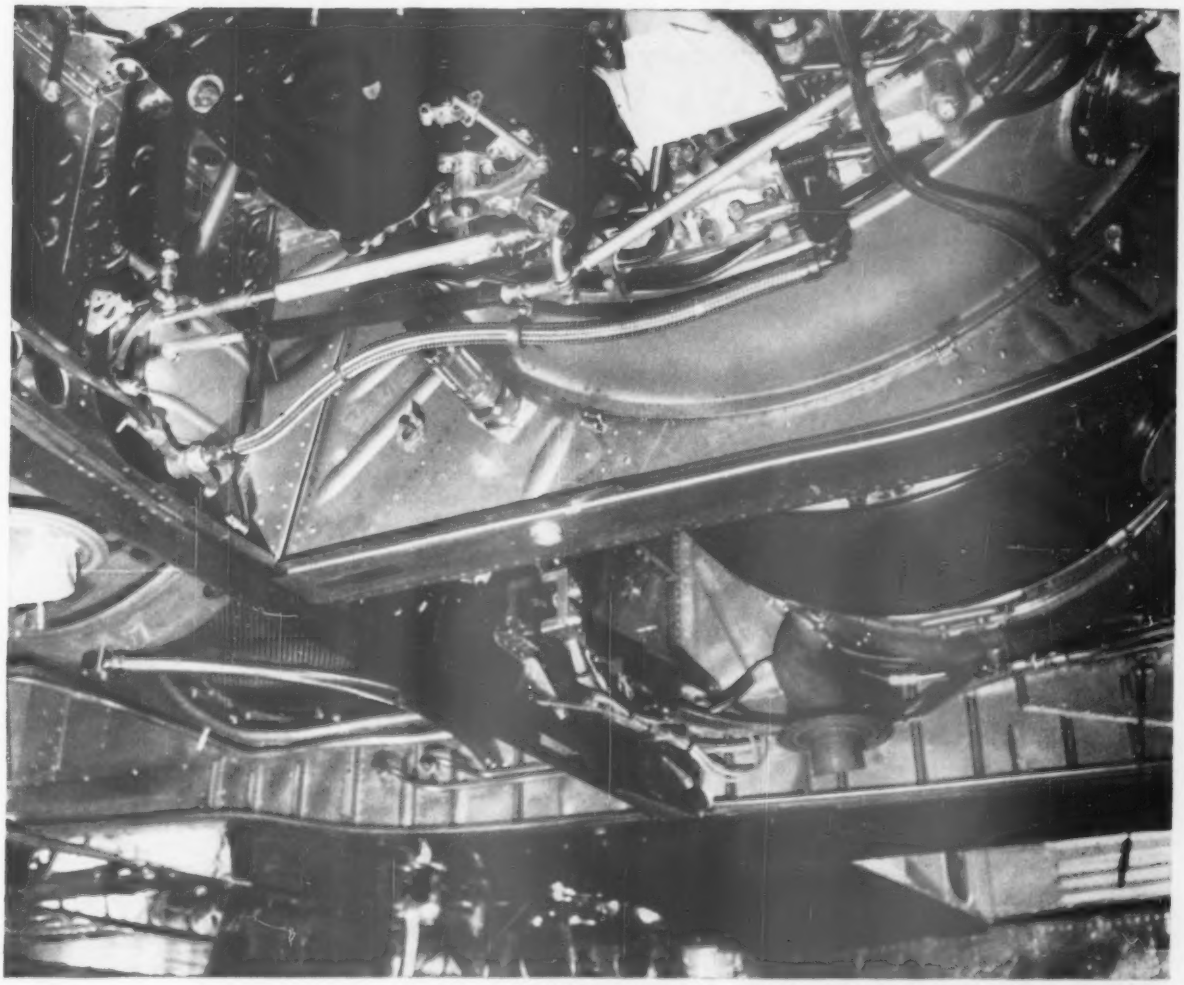

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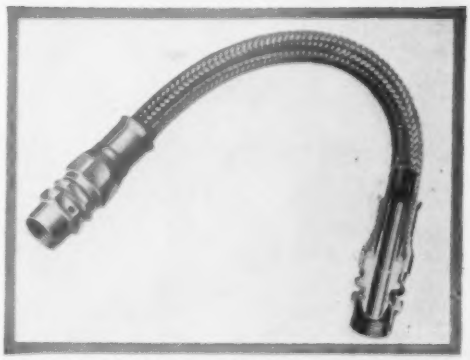

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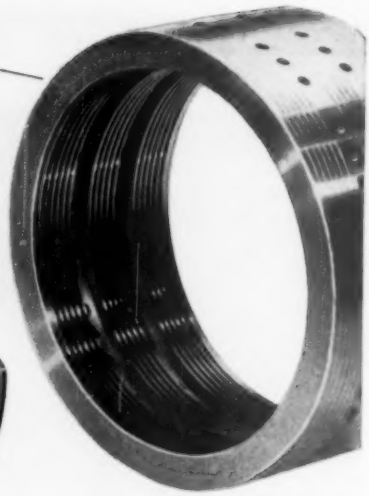

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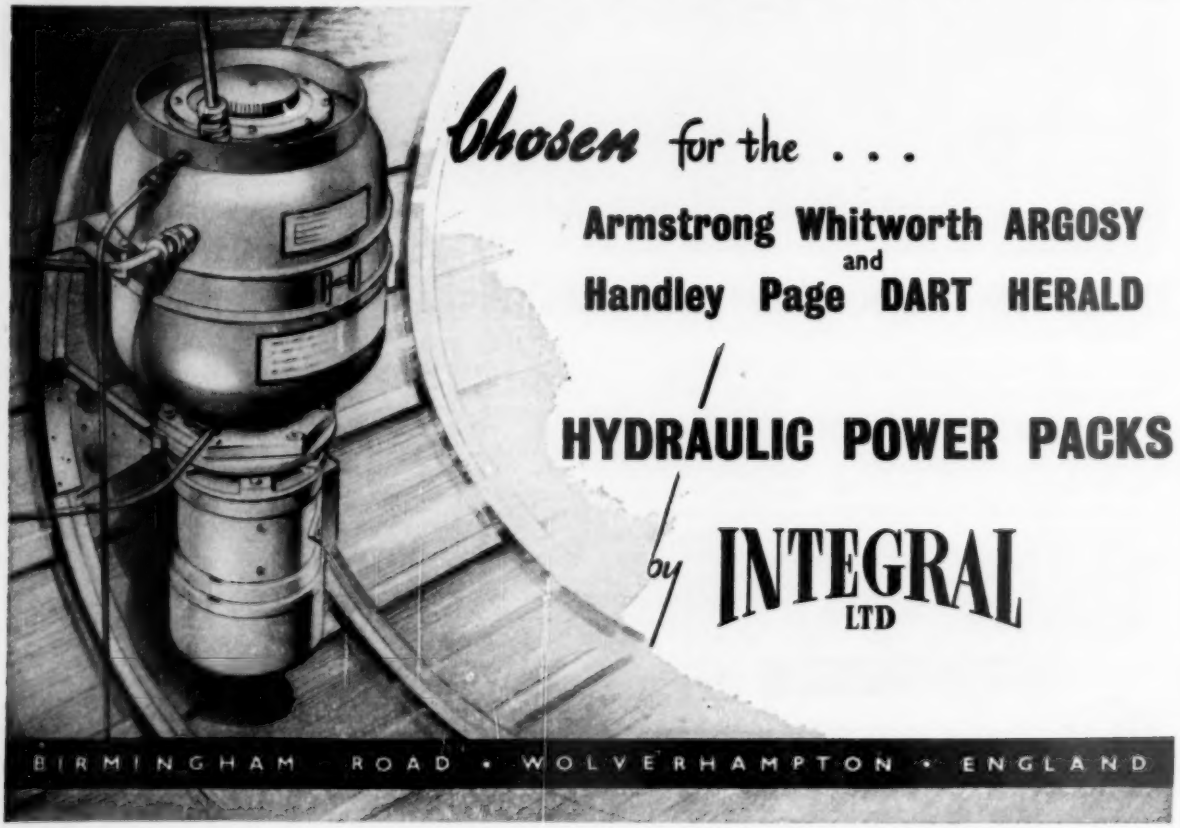

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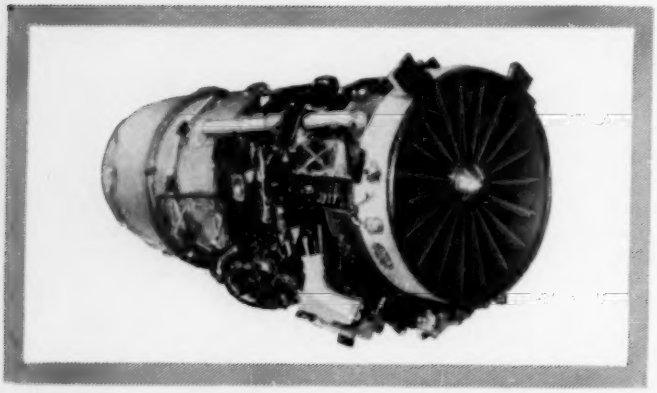

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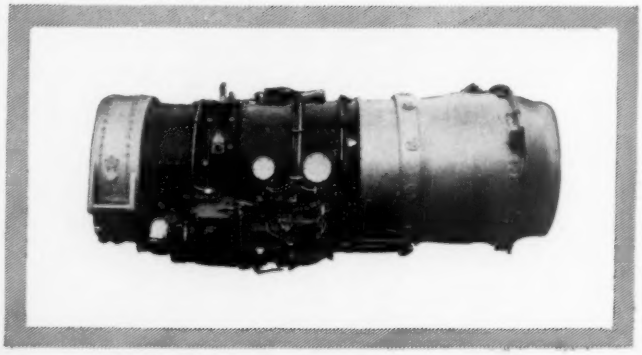

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All communications for publication in the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., Hon.F.C.A.I., F.I.A.S., F.R.Ae.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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Secretary's News Letter

December 1959

The Seventh Anglo-American Aeronautical Conference has been held. It is said, tritely perhaps, that " all good things come to an end." But many years ago I was told the addendum "only to make room for more." Already I am sure many of the delegates, not to mention their wives, are looking forward to the next Anglo-American Conference to be held on this side in 1961. Already the invitations have been sent to the Presidents of both the Institute of the Aeronautical Sciences and the Canadian Aeronautical Institute to come to Britain in the fall of 1961.

From the time I left London Airport in a B.O.A.C. Comet to the time I arrived at Prestwick in a Britannia, everything went with a pleasant and pleasing efficiency.

Many things gave great pleasure to the British delegates but perhaps the most pleasant was the continued presence of Bill Littlewood with his constant mirth-provoking duel with our President. "Roland" succeeded "Oliver" with great regularity much to the delight of appreciative audiences in both America and Canada.

That it was a good Conference everyone is agreed; to Bill Littlewood and to Paul Johnston and the Institute staff much credit is their due; for the arrangements which were made and for their many ungrudging kindnesses. A special word of thanks must be said to Mrs. Littlewood, ably assisted by Miss Marjorie Rode, for the many shows that were put on for the wives of the British delegates.

As I write I am conscious of the activity going on at the rear of the building. The Lecture Theatre is well and truly under construction. To date about £100,000 has been collected, amply demonstrating the esteem in which the Society is held by the Aeronautical Industry, for from the Industry has come the major portion of the donations. Many others, outside the Industry, have also shown their approval of the scheme by contributing. Thus dreams become reality! For many years the Society has desired a Lecture Hall, and by October 1960 it should have one thanks to the generosity of many friends as well as members.

Throughout the years members have expressed a wish for a Society Tie, and very soon this wish will be gratified, for such a tie has now been designed. It will consist of gold falcons, wings outstretched (as in the Society badge) on a navy background. It will be available to members early in 1960, and obtainable direct from the outfitters, Rowans Ltd., Buchanan Street, Glasgow, priced at one guinea. In addition a tie for Branch Members who are not members of the Society, has been designed to a similar pattern, gold falcons on a maroon ground; these will be obtainable in due course, from the Branch Secretaries. Members will be notified when the ties are ready.

Many will have heard of the sudden death of Deryck Smith on 4th December. He was well known to members of the Society, and was held in great esteem and affection.

1959 is nearing its inevitable end. It has been a crowded year with significance in the founding of New Groups and the start on the Lecture Theatre.

I wish to take this opportunity of wishing all members of the Society a Merry Christmas and a satisfactory and satisfying New Year.

A. M. Ballantyne

Secretary.

NOTICES

Anniversary Lunch—12th January 1960

Much to the regret of the President and Council, the Prime Minister, the Right Hon. Harold Macmillan, P.C., M.P., who was to have been the Guest of Honour and Principal Speaker at the Society's Anniversary Luncheon on 12th January, will be in Africa at that time. The Prime Minister has expressed his regret at being unable to be present at the Luncheon as he had looked forward to it.

Fortunately, the Minister of Aviation, The Rt. Hon. Duncan Sandys, M.P., has agreed to deputise for the Prime Minister.

Members are reminded that the Luncheon, which celebrates both the 94th Birthday of the Society and the Golden Jubilee of that Golden Year in British Aviation, 1910, will be at the Dorchester, Park Lane, London W.1, on Tuesday 12th January 1960 (at 12.30 p.m. for 1 p.m.). Tickets, 45s. each, including cocktails, are obtainable from the Secretary, 4 Hamilton Place, and ladies are welcome. An application form for tickets was inserted in the November JOURNAL and members wishing to attend should apply for tickets as soon as possible.

CHRISTMAS HOLIDAY

The Offices and Library of the Society will be closed from Thursday afternoon 24th December until 9 a.m. on Tuesday 29th December.

SECOND INTERNATIONAL CONGRESS OF THE AERONAUTICAL SCIENCES, SEPTEMBER 1960

The Second International Congress of the Aeronautical Sciences will be held from 12th to 17th September 1960, at the Eidgenossische Technische Hochschule, Zurich, Switzerland. The Opening Session at 10 a.m. on 12th September will be followed by the Second Daniel and Florence Guggenheim Lecture. The afternoon of 14th September will be free for an excursion or technical visits and lectures will only be held on the morning of 17th September if it appears to be necessary.

The subjects covered by the lectures will be:— Aerodynamics, Heat, Aerothermochemistry, Magneto-aerodynamics, Aeroelasticity, Fatigue, Materials, Flight Mechanics and Guidance in Upper Atmosphere and Space, Aero and Space Medicine, Relations between Economic and Technical Aspects of Air Transport.

The Council of the International Congress of the Aeronautical Sciences hopes that the Second Congress will be of interest not only to research men but also to scientists and engineers working on the design, production and use of aircraft missiles. Further details of the Congress will be announced shortly. Members of the Society wishing to attend the Congress should inform the Secretary.

REPRINTS

Members may be interested to know that reprints of the *Journal of the Aeronautical Sciences* are now available at the following rates from the Johnson Reprint Corporation, 111 Fifth Avenue, New York 3:—

Volumes 1-5—the set 145 dollars.
Volumes 1-2—Single Volumes 20 dollars.
Volumes 3-5—Single Volumes 35 dollars.
Volumes 6-8 are in preparation.

The same firm has Volume 1 of *Missiles and Rockets* as a reprint at 20 dollars.

Wm. Dawson and Sons Ltd., of 16 West Street, Farnham, Surrey, have reprinted the first 18 volumes (1929-46) of *Aircraft Engineering*.

The price for each of these, cloth bound, is £6 10s. 0d.

NASH COLLECTION MOVES TO LONDON AIRPORT

The Nash Collection of Veteran Aircraft, which has spent the past two years in a hangar at R.A.F. Station, Hendon, has now been transferred to its new home at the B.E.A. Engineering Base. The move was made by No. 71 M.U., commanded by Wing Commander D. E. Gibbs, A.F.R.Ae.S., and the Council wishes to record its appreciation of the careful and efficient manner in which these fragile veterans were moved. The Council also wishes to take this opportunity of thanking the Commanding Officer, Wing Commander P. Cartridge, the Station Administrative Officer, Squadron Leader K. H. W. Freeman and The Adjutant, Flight Lieutenant J. G. W. Shakespear of R.A.F. Station, Hendon, for many acts of kindness during the year in which the Historic Aircraft Maintenance Group operated at Hendon.

Work is now being resumed by the enthusiastic members of the H.A.M.G in ideal but, alas, still temporary surroundings.

CHRISTMAS LECTURES AT THE ROYAL INSTITUTION

The one hundred and thirtieth course of six Christmas lectures adapted particularly for a juvenile audience will be held at the Royal Institution, at 3 p.m. on 29th and 31st December 1959 and on 2nd, 5th, 7th and 9th January 1960.

The subject of the lectures, to be given by Dr. T. E. Allibone, F.R.S., Director, Research Laboratory, Associated Electrical Industries, will be "The Release and Use of Atomic Energy." The subscription for juveniles (aged 10 to 17) is £1 and for adults (non-members of the Royal Institution) is £2.

Further details may be obtained from The Royal Institution, 21 Albemarle Street, London W.1.

SUPPLEMENT TO OXFORD ENGLISH DICTIONARY

The following is the fourth list of aeronautical terms for the Supplement to the *Oxford English Dictionary* for which assistance in tracing early references is required. If members know of an earlier use than that given for any word in the following list they are asked to write to the Editor, Oxford English Dictionary Supplement, 40 Walton Crescent, Oxford, giving the reference(s), date, author, title, chapter and page. Earlier lists were published in the June, August and October JOURNALS.

balanced surface	1928	V. W. Pagé, *Modern Aircraft*
beaching gear	1939	*Meccano Magazine*
blade damper	1950	*B.S.I. Glossary of Aeronautical Terms*
blind-flying (instruments, and so on)	1930	*Flight*
blister (gun compartment in aircraft)	1939	*Meccano Magazine*
bombardier (bomb-aimer)	1940	*Life Magazine*
boost, sb. (also boost-compounds)	1931	*Handbook of Aeronautics*
box (aerial escort)	1941	*The Battle of Britain*
brake parachute	1951	*B.S.I. Glossary of Aeronautical Terms*
bubble sextant	1930	*Aircraft Engineering*
buffeting	1931	*The Times*
burble point, burbling point	1918	W. E. Dommett *Dictionary of Aircraft*

Change of Lecture Titles

The attention of members is particularly drawn to the Change in Titles of the Lectures on 17th December 1959 and 14th January 1960 which were originally announced as dates for the Astronautics and Guided Flight Section Lectures in the Printed Programme Card.

Discussion on Reliability of Digital Computer Systems

A series of discussion meetings on "Managerial and Engineering Aspects of Reliability and Maintenance of Digital Computer Systems" will be held on 20th and 21st January 1960 at the Institution of Electrical Engineers, Savoy Place, London W.C.2.

The Meetings are being held under the aegis of Group B, the British Group for Computation and Automatic Control, of the British Conference on Automation and Computation.

Further information may be obtained from the I.E.E. at the above address.

Civilian Studentships at the Royal Military College of Science, Shrivenham

The Royal Military College of Science, Shrivenham, offers a number of studentships to civilians each year. The course prepares students for the London University degree of B.Sc.(Special) in Chemistry, Physics or Mathematics or B.Sc.(Engineering). Students to whom awards are made are expected to join the Scientific Civil Service when they have taken their degrees.

Candidates must be under 22 years of age on the 1st October of the year of entry (or under 24 years having completed National Service) and must satisfy the conditions of the University of London for registration for the B.Sc.(Special) or B.Sc.(Eng.) degree course. Studentships carry exemption from tuition and examination fees and the student receives a maintenance allowance of £355 a year.

The preliminary qualifying examination for the courses beginning in October 1960 will be held in February 1960.

Application forms and further information may be obtained from the Ministry of Aviation, Est. 3(R)3, Room 512, The Adelphi, Strand, London W.C.2.

Acknowledgment

The Council wishes to thank Thomas Warren, Esq., 130 Wharf Street, Leicester for giving to the Library the following framed items:— Official Programme of Burton-on-Trent Aviation Week 1910; Coronation First U.K. Aerial Post postcard, postmarked Windsor, 18th September 1911 and endorsed "With Guards Brigade on Manoeuvres"; Australian Air Mail cover postmarked Melbourne, 14th December 1929, and endorsed "via Aust. & Karachi London Air Mail."

Honours Awarded to Members

Mr. W. Tye (*Fellow*) has recently been awarded the Flight Safety Foundation Aviation Week Award for 1959 for distinguished service in achieving safer utilisation of aircraft.

Annual Subscriptions

Members are reminded that their annual subscriptions become due on 1st January 1960. The rates are:—

	Home £ s. d.	*Abroad* £ s. d.
Fellows	8 0 0	7 0 0
Fellows (over 65)	5 0 0	4 0 0
Associate Fellows	6 0 0	5 0 0
Associate Fellows (over 65)	4 0 0	3 0 0
*Associates	5 0 0	5 0 0
Associates (over 65)	3 0 0	3 0 0
Graduates (aged under 26)	2 10 0	2 10 0
Graduates (aged 26 and over)	3 0 0	3 0 0
Students (aged under 21)	1 10 0	1 10 0
Students (aged 21 and over)	2 0 0	2 0 0
Companions	4 0 0	4 0 0
Companions (over 65)	3 0 0	3 0 0
Companions (No Journal)	2 10 0	2 10 0
Founder Members	— — —	— — —

*Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscriptions will be reduced by £1 10s. 0d. to £3 10s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership. Remittances should be made payable to the Royal Aeronautical Society.

Courtesy "The Aeroplane and Astronautics"

Courtesy Holland and Hannen and Cubitts (Great Britain) Ltd.

Lecture Theatre Progress.—The photograph on the left, taken towards the end of October, shows the Secretary surveying the first stages of the work on the Lecture Theatre. The photograph on the right, taken on 4th December, shows the progress made on the foundations.

LECTURE THEATRE APPEAL

The following lists show further donations received up to the time of going to press.

Donations

	£	s.	d.	£	s.	d.
Previous total (after minor adjustments)				9029	7	3
Aer Lingus Ltd.	250	0	0			
W. N. Alcock, Esq.	11	0	0			
E. F. Anderson, Esq.	1	0	0			
G. O. Anderson, Esq.	2	2	0			
Anonymous (2)	1	5	0			
A. A. Avenell, Esq.	5	5	0			
J. C. A. Baldock, Esq.	2	2	0			
C. H. Barnes, Esq.	3	3	0			
G. E. Barrett, Esq.	1	1	0			
Sqn. Ldr. G. F. Bates	2	0	0			
Flt. Lt. A. W. Bedford	5	5	0			
Bells Asbestos & Engineering Ltd.	21	0	0			
R. M. Berry, Esq.	1	1	0			
Lt. Col. C. O. Blakemore ...	2	0	0			
K. A. Bolonkin, Esq.	5	0	0			
James Booth & Co. Ltd.	105	0	0			
R. H. Botterill, Esq.	2	2	0			
Flt. Lt. R. W. Bray	3	3	0			
Cdr. E. M. Brown	2	2	0			
Air Cdre. Sir Vernon Brown ...	3	3	0			
Brough Branch (*see* special list) ...	105	0	0			
Capt. G. R. Buxton	2	2	0			
A. R. W. Cane, Esq.	5	0	0			
Sqn. Ldr. E. J. Cashman	1	1	0			
Dr. W. Cawood	10	10	0			
D. S. Challener, Esq.		10	0			
P. G. Chaplin, Esq.	2	2	0			
E. K. Cole, Ltd.	157	10	0			
R. J. F. Coppage, Esq.	1	1	0			
J. Counihan, Esq.	2	10	0			
R. M. Cracknell, Esq.	3	3	0			
A. L. B. Dawson, Esq.	2	2	0			
Derby Branch	25	0	0			
D. Diamond, Esq.	3	3	0			
R. S. Dickson, Esq. (U.S. $10) ...	3	10	2			
E. R. Dinsmore, Esq.	1	1	0			
E. R. Dudley (*see* Weybridge Branch)						
W. H. Dudley, Esq.	1	1	0			
Prof. W. J. Duncan	5	5	0			
J. N. Edney, Esq.	1	0	0			
Wg. Cdr. T. W. Ellcock	2	2	0			
Engineering Staff (Bristol Siddeley Engines Ltd.)	7	10	0			
R. G. Evans, Esq.	3	3	0			
P. J. Farmer, Esq.	2	0	0			
V. N. Ferriman, Esq.	2	2	0			
Field Aircraft Services Ltd. ...	26	5	0			
J. C. Floyd, Esq.	5	5	0			
I. V. Franklin, Esq.	1	10	0			
L. G. Frise, Esq.	10	0	0			
Sir Harry Garner	25	0	0			
Wg. Cdr. I. D. H. Gibbins ...	4	0	0			
A. J. Gidynski, Esq.	2	0	0			
Gloucester and Cheltenham Branch	25	0	0			
M. J. Goldsmith, Esq.	1	1	0			
B. I. Grant, Esq.	1	1	0			
P. M. Gray, Esq.	1	0	0			
H. S. Green, Esq.	3	3	0			
Sqn. Ldr. W. B. Green	3	3	0			
A. H. C. Greenwood, Esq. ...	5	5	0			
W. C. Hannah, Esq.	1	1	0			
R. C. Hastings, Esq.	2	0	0			
Hatfield Branch	75	0	0			
Helicopter Association of G.B. Ltd.	52	10	0			
H. G. Herrington	10	10	0			
Lord Hives	10	0	0			
H. M. Hobson, Ltd.	52	10	0			
Sqn. Ldr. E. J. Holden	2	0	0			
R. C. Holliday, Esq.	2	2	0			
Air Cdre. S. W. R. Hughes ...	2	2	0			
Sqn. Ldr. O. L. Hyde (additional)	2	0	0			
Gp. Capt. J. E. Innes-Crump ...	2	2	0			
Isle of Wight Branch	21	0	0			
J. L. A. Jarry, Esq.	5	0	0			
J. R. T. Gibson Jarvie, Esq. ...	5	5	0			
A. E. Jefferson, Esq.	3	0	0			
Col. H. T. Jessop	5	5	0			
C. F. Joy, Esq.	5	0	0			
E. D. G. Kemp, Esq.		10	0			
E. D. King, Esq.	2	2	0			
M. S. Kuhring (Canada $25) ...	9	5	0			
C. V. Lane, Esq.	2	2	0			
I. R. Liddell, Esq.	2	2	0			
W. G. Lisle, Esq.	2	2	0			
Sqn. Ldr. G. A. B. Lord	1	1	0			
W. T. Lord, Esq.	1	0	0			
G. Lyon, Esq.	1	1	0			
G. H. Macdonald, Esq.		10	6			
R. H. Macmillan, Esq.	2	2	0			
L. Malec, Esq.	2	2	0			
Charles Maley (U.S. $100) ...	35	10	6			
Marshalls Flying Schools Ltd. ...	15	15	0			
Wg. Cdr. R. F. Martin	1	1	0			
Lt. Col. J. P. A. Martindale ...	5	0	0			
Merthyr Tydfil Branch	25	0	0			
T. H. Mountain, Esq.	2	0	0			
J. A. McTaggart, Esq.	2	2	0			
W. N. Neat, Esq.	5	0	0			
D. R. Newman, Esq.	5	0	0			
Gp. Capt. G. L. O'Hanlon ...	3	3	0			
S. M. Parker, Esq.	5	0	0			
T. O. Peel, Esq.	2	2	0			
R. C. Pennicott, Esq.	1	1	0			
F. C. Petts, Esq.	2	2	0			
E. G. Preston, Esq.	2	2	0			
Wg. Cdr. C. N. S. Pringle ...	5	5	0			
G. G. R. Pudney, Esq.	1	1	0			
H. P. Punter, Esq.	2	2	0			
Sqn. Ldr. J. N. Quick	2	2	0			
J. L. Raynes, Esq.	3	3	0			
Reading Branch	20	0	0			
Prof. S. C. Redshaw	3	3	0			
Lt. A. Reynolds, R.N.	2	2	0			
D. M. Richards, Esq.	1	1	0			
Gp. Capt. S. Roath	2	2	0			
G. Robinson, Esq.	1	1	0			
W. H. Ruthven, Esq.	1	1	0			
R. G. M. Scarfe, Esq.	2	0	0			
R. H. Schlotel, Esq.	10	0	0			
J. S. Shapiro, Esq.	2	2	0			
E. F. Simmonds, Esq.	1	1	0			
W. R. Simons, Esq.	2	2	0			
H. Smith, Esq.	5	5	0			
W. Socha, Esq.	5	0	0			
J. Solvey, Esq.	3	3	0			
Air Marshal Sir Ralph Sorley (in memory of Henry Tizard) ...	7	0	0			
Air Marshal H. D. Spreckley ...	3	3	0			
Prof. H. B. Squire	5	0	0			
Gp. Capt. J. H. Stevens	2	0	0			
A. E. Swain, Esq.	1	1	0			
R. E. Swift, Esq.	2	2	0			
Air Cdre. N. A. Tait	5	5	0			
W. C. Lyall Taylor, Esq.	3	3	0			
Flt. Lt. A. B. Thompson (additional)	2	0	0			
C. Torkington, Esq.	1	0	0			
P. G. Tranter, Esq.	1	10	0			
Gp. Capt. P. G. Tweedie	2	2	0			
J. V. Vint, Esq.	1	0	0			
A. Vines, Esq.	5	0	0			
J. B. Waite, Esq.	2	2	0			
F. G. Walker, Esq.	5	0	0			
T. Wayne, Esq.	3	3	0			
G. Webb, Esq.		10	0			
Sqn. Ldr. N. G. H. Weeks ...	2	0	0			
Weybridge Branch (additional) ...	72	12	0			
„ (per E. R. Dudley)	2	2	0			
P. H. Wilkinson, Esq.	10	0	0			
Col. L. J. Cardew Wood	5	5	0			
H. Wood, Esq.	2	12	6			
Worshipful Company of Armourers and Braziers	5	5	0			
Air Cdre. W. R. Worstall	2	2	0			
Dr. S. Yusuff	3	0	0			
	1518	15	8			
				£10,548	2	11

7 Year Covenants

	£ s. d.	£ s. d.
Previous total (after minor adjustments)		2823 8 10
G. Beardshall, Esq.	5 0 0	
R. A. Burberry, Esq.	1 0 0	
R. A. Burton, Esq.	1 0 0	
Air Cdre. B. A. Chacksfield ...	1 1 0	
Ciba (A.R.L.) Ltd.	20 0 0	
A. L. R. Dziwinski, Esq.	1 0 0	
A. G. M. Elliott, Esq.	1 0 0	
English Electric Aviation Ltd. ...	500 0 0	
G. B. S. Errington, Esq.	1 1 0	
Flt. Lt. F. H. Gray	1 0 0	
F. B. Greatrex, Esq.	1 1 0	
Dr. G. S. Hislop	2 2 0	
F. R. S. Holben, Esq.	1 0 0	
D. M. Jameson, Esq.	2 0 0	
A. W. Kitchenside, Esq.	1 0 0	
Air Cdre. E. Knowles	1 1 0	
J. Lewis, Esq.	1 0 0	
Wg. Cdr. F. C. Lowe	1 0 0	
Air Marshal Sir A. McDonald ...	2 0 0	
R. H. Payne, Esq.	1 0 0	
E. W. Pike, Esq.	5 0 0	
F. H. Pollicutt, Esq.	2 2 0	
J. D. Poole, Esq.	1 0 0	
E. F. Relf, Esq.	2 0 0	
Prof. A. Robertson	2 2 0	
D. C. Robertson, Esq.	10 0	
Rolls-Royce Ltd.	612 10 0	
G. A. Saywell, Esq.	2 0 0	
Short Bros. & Harland Ltd. ...	87 10 0	
C. W. Simpson, Esq.	1 1 0	
S. Smith & Sons (England) ...	1000 0 0	
Sqn. Ldr. J. P. Tyszko	1 1 0	
Unbrako Socket Screw Co. Ltd. ...	50 0 0	
Sqn. Ldr. R. H. Vernon	1 0 0	
Gp. Capt. G. E. Watt	2 2 0	
Westland Aircraft Ltd.	245 0 0	
Fg. Off. A. Wilding	1 0 0	
D. R. Willmer, Esq.	2 0 0	
Prof. A. D. Young	2 0 0	
	2565 4 0	
		*£5388 12 10

**With Income Tax at the present standard rate of 7s. 9d. in the £ this figure should produce £61,540 (approx.) over the 7 year period.*

10 Year Covenants

	£ s. d.	£ s. d.
Previous total	612 10 0	
Bristol Siddeley Engines Ltd. ...	1000 0 0	
		*£1612 10 0

**With Income Tax at the present standard rate of 7s. 9d. in the £ this figure should produce £26,325 (approx.) over the 10 year period.*

Annual Payments (unspecified period)

	£ s. d.	£ s. d.
Previous total		71 7 0
J. A. H. Bailie, Esq.	3 0 0	
T. F. Francis, Esq.	5 0 0	
Wg. Cdr. R. Storey	1 1 0	
M. H. Swift, Esq.	2 0 0	
T. Williams, Esq.	1 0 0	
	12 1 0	
		£83 8 0

GRAND TOTAL (approximately) **£98,593**

Further promises amounting to £6,432 had been received up to time of going to press, and Donations in kind promised by firms are valued at £3,500 (approx.).

The following have also subscribed but do not wish the amounts of their contributions to be published:—

G. M. Addison, Esq.
Flt. Lt. H. Barrett
Sqn. Ldr. W. A. Beedie
G. E. D. Bonham-Carter, Esq.
R. H. Bridgman, Esq.
Sqn. Ldr. L. Byram
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Dr. A. H. Chilver
Gp. Capt. P. Cleaver
Sqn. Ldr. E. T. Curran
Fg. Off. B. A. Daniels
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S. H. Freemantle, Esq.
J. H. Ford, Esq.
R. Gemmell, Esq.
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H. C. H. Merewether, Esq.
F. A. Mason, Esq.
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Wg. Cdr. J. W. McKelvey
A. N. Page, Esq.
A. D. W. Pimm, Esq.
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Dr. A. K. Rao
J. H. Rea, Esq.
S. T. A. Richards, Esq.
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Sqn. Ldr. R. C. Rogers
Fg. Off. P. T. Ryans
G. Selwood, Esq.
R. Storey, Esq.
R. G. Taylor, Esq.
J. M. Tomkins, Esq.
A. J. Watson, Esq.
J. Weddup, Esq.

BROUGH BRANCH

The following donated to the total listed in the main list of donations:—

LIST 1

	£ s. d.	£ s. d.
F. R. Banks, Esq.	10 10 0	
J. B. Bucher, Esq.	5 0 0	
H. Brumby, Esq.	1 0 0	
M. G. K. Byrne, Esq.	2 0 0	
Wg. Cdr. Chalmers	2 2 0	
T. A. Collinson, Esq.	1 0 0	
J. I. Dodds, Esq.	2 0 0	
K. Essex-Crosby, Esq.	1 0 0	
G. B. Fenton, Esq.	2 0 0	
T. Gibson, Esq.	3 3 0	
J. Hall, Esq.	1 0 0	
A. D. Howarth, Esq.	3 3 0	
Dr. A. King, Esq.	1 0 0	
B. P. Laight, Esq.	10 10 0	
A. V. Leake, Esq.	1 0 0	
Capt. E. D. G. Lewin	5 5 0	
H. Maynard, Esq.	1 0 0	
K. B. Marsh, Esq.	1 0 0	
C. C. Parsons, Esq.	1 1 0	
G. R. I. Parker, Esq.	5 5 0	
G. E. Petty, Esq.	5 0 0	
A. P. N. Potts, Esq.	1 0 0	
N. E. Rowe, Esq.	5 5 0	
J. T. Stamper, Esq.	3 0 0	
C. P. J. Truyens, Esq.	1 0 0	
E. Turner, Esq.	10 10 0	
V. E. Vause, Esq.	1 10 0	
D. J. Whitehead, Esq.	5 0 0	
E. Wilks, Esq.	1 0 0	
T. A. Wolstenholme, Esq. ...	1 0 0	
C. J. Wood, Esq.	1 0 0	
S. Wrightson, Esq.	1 1 0	
		£96 5 0

LIST 2

I. Ainsley, Esq.	C. Jones, Esq.
P. J. Bellerby, Esq.	D. Makepeace, Esq.
P. G. Boid, Esq.	J. H. Marsh, Esq.
J. R. Cockerill, Esq.	J. F. Nash, Esq.
G. B. Ducker, Esq.	G. A. Pullinger, Esq.
A. M. H. Dunn, Esq.	B. Reuben, Esq.
A. Forrester, Esq.	D. Stead, Esq.
J. P. Hamilton, Esq.	J. Snell, Esq.
H. T. Howard, Esq.	W. S. Bannister, Esq.

TOTAL £105 0 0

DIARY

LONDON

17th December

The Engineering Advantages of Rear Engines in Pure Jet Transport. E. S. Allwright. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

7th January 1960

YOUNG PEOPLE'S LECTURE—Flying versus the Human Machine. Dr. G. Melvill Jones. The Royal Society of Arts, 6 John Adam Street, W.C.2. 3 p.m.

14th January

Future of Automatic Control on Fixed Wing Aircraft. Prof. G. A. Whitfield. The Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

15th January

AGRICULTURAL AVIATION GROUP LECTURE—Biological Factors in Agricultural Aviation. C. V. Dadd. Library, 4 Hamilton Place. 7 p.m.

19th January

LECTURE—Some Aerodynamic Problems of Engine Installation. Dr. J. Seddon. Library, 4 Hamilton Place. 7 p.m.

21st January

MAIN LECTURE AT THE CAMBRIDGE BRANCH—Research at the College of Aeronautics, Cranfield. Professor A. J. Murphy. No. 1 Lecture Hall, Engineering Laboratories, Cambridge University. 8.15 p.m.

GRADUATES' AND STUDENTS' SECTION

13th January 1960

Aviation Medicine in the Space Age. Wing Cdr. F. Latham. Library, 4 Hamilton Place. 7.30 p.m.

BRANCHES

10th December

Cambridge—Film Show. No. 1 Lecture Hall, Cambridge University Engineering Labs. 8.15 p.m.

Cheltenham—The Development of Automatic Landing for Civil Airline Operations. K. Fearnside. St. Mary's College. 7.30 p.m.

Merthyr Tydfil—Supersonic Propulsion. Dr. R. R. Jamison.

Yeovil—Metal Spinning Practice. C. L. S. Fraser. Park School, Park Road. 7.30 p.m.

11th December

Belfast—Annual Dance. Midland Hotel, Belfast.

Birmingham and Wolverhampton—Man Powered Flight. J. L. Nayler. Engineering Centre, Birmingham. 7.30 p.m.

14th December

Henlow—Presidential Address. R. Hills. The Assembly Hall, R.A.F. Technical College, Henlow. 7.45 p.m.

15th December

Bristol—Junior Committee Lecture. The Supersonic Airliner. R. G. Thorne. Filton House. 6 p.m.

16th December

Coventry—Film Evening. Herbert Art Gallery. 7.30 p.m.

Glasgow—Graduates' and Students' Section—Lecture by T. Wood. Engineering Building, University of Glasgow. 7.30 p.m.

Preston—The Next Generation of Civil Aircraft. G. H. Lee. Queen's Hotel, Lytham. 7.45 p.m.

Reading—M.A.T.S. Capt. J. E. Christie. Top Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

17th December

Isle of Wight—Annual General Meeting and Film Show. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, East Cowes. 6 p.m.

18th December

Weybridge—Annual Dance.

4th January 1960

Boscombe Down—Escape from Military Jet Aircraft. Wing Cdr. J. Jewell. Lecture Hall, A. & A.E.E. 5.30 p.m.

Derby—The Use of Rockets in Scientific Research. Prof. H. S. W. Massey. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

5th January

London Airport—Helicopters. P. Brooks. Lecture Hall, Fairey Aviation Co., Hayes. 6.15 p.m.

Luton—"No Highway". C. F. Toms. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

6th January

Bristol—The Satellite Programme. Dr. W. F. Hilton. Filton House. 6 p.m.

Brough—The Art of Developing Aero Engines. A. C. Lovesey. Royal Station Hotel Writing Room. 7.30 p.m.

Cambridge—Film Show. No. 1 Lecture Hall, Cambridge University Engineering Labs. 8.15 p.m.

Hatfield—Social Evening. De Havilland Restaurant. 6.15 p.m.

Southampton—The Hovercraft. C. S. Cockerell. Engineering Lecture Theatre, University of Southampton. 8 p.m.

Swindon—Automatic Flight—The British Story. Sir George Gardner. The College, Victoria Road. 7.30 p.m.

Weybridge—The Work of Vickers Research Ltd. Dr. J. R. Green. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

7th January

Belfast—Experiences on the Trans-Antarctic Expedition. Wing Cdr. J. A. Lewis. Lecture Hall LG8, David Keir Building, Queen's University. 7 p.m.

Isle of Wight—Philosophy in Structural Design. Dr. A. H. Chilver. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, East Cowes. 6 p.m.

Yeovil—Helicopter Test Flying. W. H. Sear. Park School, Park Road. 7.30 p.m.

11th January

Henlow—Development of High Performance Sports Cars. F. A. Costin. The Assembly Hall, R.A.F. Technical College, Henlow. 7.45 p.m.

12th January

Gloucester—Proteus Icing Experience. G. F. Pitts. Wheatstone Hall, Brunswick Road. 7.30 p.m.

13th January

Bristol—Discoveries from the Study of Satellite Orbits. D. G. King-Hele. Filton House. 6 p.m.

Chester—Parachutes and Parachute Design. S. B. Jackson. Lecture Theatre, Grosvenor Museum. 7.30 p.m.

14th January

Glasgow—Graduates' and Students' Section—Lecturettes by Section members. Scottish Aviation Ltd., Prestwick. 7.30 p.m.

15th January

Birmingham and Wolverhampton—Aircraft Heat Exchangers. Dr. W. Bergwerk. Marston Excelsior Ltd., Wolverhampton. 7.30 p.m.

Preston—Annual Dinner and Dance. Imperial Hotel, Blackpool. 8 p.m.

18th January

Derby—Annual General Meeting and Film Show. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

Halton—Aircraft Carriers. J. C. Lawrence. Branch H.Q., R.A.F. Halton. 6.45 p.m.

19th January

Glasgow—Development of the Olympus Turbo-jet. E. Mosedale. Royal College of Science and Technology. 7.15 p.m.

20th January

Bristol—Space Medicine. Wing Cdr. P. D. C. V. Whittingham. Filton House. 6 p.m.

Brough—Young People's Christmas Lecture—Flying with the Trans-Antarctic Expedition. Wing Cdr. J. H. Lewis. Newland High School, Cottingham Rd., Hull (Afternoon).

Coventry—Transport Command. Gp. Capt. F. C. Griffiths. Herbert Art Gallery. 7.30 p.m.

Preston—Aircraft Structural Testing. H. C. Channon. Queen's Hotel, Lytham. 7.45 p.m.

Reading—Airline Routing. A. Williams. Top Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

21st January

Cambridge—MAIN SOCIETY LECTURE—Research at Cranfield. Professor A. J. Murphy. No. 1 Lecture Hall, Cambridge University Engineering Laboratories. 8.15 p.m.

Isle of Wight—Aircraft Production. A. Vines. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, East Cowes. 6 p.m.

25th January

Henlow—Flying Boats. R. Stanton-Jones. The Assembly Hall, R.A.F. Technical College, Henlow. 7.45 p.m.

ELECTIONS

The following is a list of elections and transfers of membership of the Society:—

Associate Fellows

William Barnett
Bryan Eric Butler
Bikash Kumar Ghosh
Arthur Alan Goddard
Ronald Mollison Guthrie
Norman Henry Chriss Harris
Barkat Husain
David Michael Lumb *(from Graduate)*
William Henry Mares
Thomas Henry Mountain *(from Graduate)*
Eric Rose
Allan Sadler
John Beaumont Scott-Wilson
Vivek Ranjan Sinha *(from Graduate)*
Frederick William Stokes
John Brian Sutcliffe
Oliver Geoffrey Taylor
Michael John Webber *(from Graduate)*
David Wilkinson *(from Graduate)*
Kenneth Gabriel Williams
Fritz Alfred Winternitz
John Samuel Woolland

Associates

Herbert Briggs
Albert Victor Terence Dike
Reginald Royston Ferris
John Edwin Gwilliam *(from Companion)*
John Lowen
Terence Wilson Tyrell McComb
Piyasena Samarakone
Moshe Spiegel

Graduates

Derek William Altham *(from Student)*
John Ashcroft
John Miles Chapman
Boguslaw Chojnowski *(from Student)*
Colin Frederick Cook
David John Dibble
Roy Etchells
Malcolm Fearenside
Joseph Thomas Gallagher
David Rogers Hammett
Bruce Moodie Hill
Gwynne Mason Hitchings
John Michael Hold *(from Student)*
Ian Christopher Ashley Leonard
John McFarland
Richard McKay *(from Student)*
John William Mair
Graham John Marrs
Kenneth Henry Mitchell
Frederick Charles Parkin
John Edwin Punter
John Derek Jeremy Robson
Ronald George Maynard Scarfe *(from Student)*
Terry Henry Alister Summers
James Francis Swale
John Tribe
Leslie James Warren *(from Student)*
Peter Murray Wells
Ralph Williams
Malcolm Daniel Wright *(from Student)*
Geoffrey Edgar Frank Young *(from Student)*

Students

Paul Nolan Boon
Francisco Jose De Queroz De Azevedo e Bourbon
Jeremy Roger Coldrick
Joseph Fisher
Bernard Garnett
Raymond Arthur Gartside
Noel Raymond Hartley
John Douglas Irvine
Derek Alan Lock
Russell Allan Loxley
Michael Midderigh
Khwaja Nizamuddin
Alec George Read
Peter Welby Offord Skinner
Kenneth Arthur Clive Smith
Rodney Charles Squires

Companions

Brian Keith Hunter
Brian Mellor
Gerald Frederick Wyatt

AMELIA EARHART SCHOLARSHIP GRANTS TO WOMEN

Zonta International offers Amelia Earhart Scholarship grants to women for graduate study in Aeronautical Engineering. Grants of $2,500 will be awarded to the best qualified candidates in June 1960 for the 1960-61 college year. Applicants must hold a bachelor's degree in a science acceptable for advanced aeronautical studies in an approved college of their choice.

Applications must be filed by 1st March, 1960. Further details and application forms may be obtained from Dr. Helen Pearce, 490 Oak Street, S.E., Salem, Oregon, U.S.A.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS PREPRINTS

The American Society of Mechanical Engineers have sent the following specimen papers as likely to be of interest to Members. Copies are obtainable from A.S.M.E (29 West 39th Street, New York, 18) price 80 cents or, to members of that body, 40 cents.

59-SA-31 "Staged Supersonic Transports. The Small Airplane Returns." A. Daskin, L. Feldman, E. A. Sanlorenzo.
A study (by three members of Applied Science Laboratories Inc.) indicating operational and economic advantages of operating staged aeroplanes at high supersonic speeds for mission ranges of commercial interest.

59-SA-32 "Designing Tomorrow's Commercial Supersonic Transport Engine." G. C. Rapp.
Reviews the requirements of integrating the Mach 2-Mach 3 engine with a suitable airframe. Some of the problems are considered and solutions indicated.

59-SA-40 "Technical and Economic Factors of Supersonic Transport." F. A. Payne.
Technical factors having a major effect on design and operations are reviewed with the choices which are directed by economic reasons.

59-SA-51 "The Shock Wave Noise Problem of Supersonic Aircraft." H. H. Hubbard and D. J. Maglieri.
The objects of this paper are to describe the nature of the sonic boom and to indicate the manner in which it may affect transport aeroplane design and operations.

59-SA-64 "The Importance of Qualitative Factors in VTOL Transport Selection." L. R. Novak.
Highlights the qualitative features while retaining an over-all perspective by reference to quantitative factors. Requirements in VTOL are emphasised, taking into consideration future planning.

SOCIETY OF AUTOMOTIVE ENGINEERS

The following three S.A.E. papers were each presented to different meetings of that Society and differ in this respect from the usual collection of preprints which they kindly present to the Library.

S.188 Lippisch, A. M. "The Aerodyne—a New Concept of Flight" (presented at Wichita, 19th February).

S.191 Leverett, M. C. "Some Views on Aircraft Nuclear Propulsion" (presented at the Metropolitan Section, 24th March).

S.194 Hohmann, C. J. "Missile Cryogenics—the Handling of Liquid Gas" (presented at Washington, 17th March).

JOURNAL BINDING

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Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Members are asked to be certain that the address to which they want their Journals sent is the same on their letters to the Lewes Press and to the Society.

News of Members

Group Captain R. Aldwinckle (*Associate Fellow*) formerly Director of Instrument and Electrical Engineering A.F.H.Q., Ottawa, Canada, is now with the Canadian Joint Staff, Washington D.C. in a supernumerary capacity for two years postgraduate studies at the University of Michigan.

A. W. R. Allcock (*Graduate*) formerly with Sir W. G. Armstrong Whitworth (Aircraft) Ltd., at Coventry, is now a Propulsion Aerodynamicist with Hawker Siddeley Aviation Advanced Project Group at Kingston-on-Thames.

William Barnett (*Associate Fellow*) formerly a Senior Reliability Engineer with Fairey Aviation Ltd., Heston, is now a Production Controller with the same firm.

Eric M. Bell (*Associate*) formerly with Convair of San Diego, is now Design Engineer with Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

Sqn. Ldr. C. L. Bessey (*Associate Fellow*) formerly Supplies Superintendent (New Projects), B.O.A.C., London Airport is now Planning Controller (Engineering and Maintenance), B.O.A.C.

Flt. Lt. D. A. Cartwright (*Associate*) formerly with the Queen's Flight, R.A.F., Benson, is now Engineer Leader of 511 Squadron, R.A.F. Lyneham.

G. F. Chalmers (*Associate Fellow*) formerly Chief Flight Test Engineer with Saunders-Roe Ltd., is now the Manager of the newly formed Strain Gauge Division with the same firm.

Mahesh Chandra (*Graduate*) formerly in the Design Office of Folland Aircraft Ltd., Hamble, is now with the Directorate of Technical Development and Production (Air) under the Defence Ministry, Government of India, as Scientific Officer (Structures II) at New Delhi.

J. R. Cowell (*Associate*) formerly an Engineer, Instrument Wing, with English Electric Co., Luton, is now a Senior Engineer with Avien, Long Island, New York.

Captain J. Doherty (*Associate*) Royal Canadian Navy, is now Assistant Chief of Naval Technical Services (Air), Royal Canadian Naval Headquarters, Ottawa.

John Dubbury (*Associate Fellow*) formerly with A. V. Roe Ltd., Malton, Ontario, is now on the Technical Staff of R.C.A. Ltd., Burlington, Mass.

A. Duch (*Graduate*) formerly with Sir George Godfrey and Partners Ltd., London, is now with Canadian Pratt and Whitney Aircraft Co., Montreal.

Wind Cdr. H. H. Eccles (*Associate Fellow*) on completion of his tour of duty in the U.S.A. will take over Command at R.A.F. Manby, in March 1960.

P. J. Farmer (*Associate Fellow*) Acting Editor of *Data Processing*, has been appointed Editor of that journal.

Flt. Lt. V. J. Glanville (*Associate*) formerly Instructor at the Royal Air Force Technical College, Henlow, is now O.C., A.S.F., Royal Air Force, Tengah, Singapore.

A. Neil Gobby (*Graduate*) formerly with Hunting Engineering Ltd., Luton Airport is now a Lecturer in the Department of Aeronautical and Mechanical Design, Hatfield Technical College.

Guest Hake (*Associate Fellow*) formerly Quality Control and Inspection Manager with Avro Aircraft Ltd., Malton, Ontario, has resigned and is now returning to the United Kingdom.

Arthur D. Hardinge (*Associate*) formerly with Avro Aircraft Ltd., Malton, is now with Philips Electric Industries in the Quality Control Department, Ontario.

R. Paul Harrington (*Associate Fellow*) formerly Professor of Aeronautical Engineering, Rensselaer Polytechnic Institute, has been appointed Professor and Head of the Dept. of Aeronautical Engineering, University of Cincinnati.

G. B. Hibbs (*Associate Fellow*) formerly an Engineer in the Project Department at Vickers-Armstrongs (Aircraft) Ltd., is now a Project Designer, Bristol Aircraft Ltd.

Flt. Lt. K. F. Hopkins (*Associate Fellow*) formerly Officer Commanding the Supplementary Storage Area is now with the Nuclear Weapons Squadron of the Weapons Wing, Central Servicing Development Establishment, Dereham, Norfolk.

Group Capt. E. M. T. Howell (*Associate Fellow*) formerly Chief Armament Officer, H.Q. Bomber Command, has been appointed Director of Air Armament Research and Development, Ministry of Aviation, with effect from 1st January 1960.

Flt. Lt. J. N. Hullah (*Associate Fellow*) formerly Flight Safety Engineer, Headquarters F.E.A.F. is now Senior Engineering Officer at R.A.F. Hullavington.

Group Captain A. M. Jardine (*Associate*) formerly in Command of R.C.A.F. Station, St. Hubert, is now with the Directorate of Air Intelligence, Air Force H.Q. Ottawa.

E. T. Jones (*Fellow*), Deputy Controller (Overseas Affairs), Ministry of Aviation has been elected Deputy Chairman of AGARD.

Garth Owen Jones (*Associate Fellow*) formerly Factory Manager, I.C.I. Metals Light Alloy Division, Waunarlwydd, Swansea has been appointed Works General Manager, Imperial Aluminium Co. Ltd., Waunarlwydd, Swansea.

W. Kuzyk (*Associate Fellow*) formerly Senior Project Research Engineer, Avro Aircraft, Toronto, is now a Senior Engineer, Research and Development Systems, John Oster Manufacturing Co. Inc., Avionics Division, Wisconsin.

P. C. F. Linstead (*Student*) formerly a Designer/Draughtsman with A. Frazer-Nash, is now a Designer/Draughtsman with the Australian Atomic Energy Commission, Research Establishment, at Lucas Heights, New South Wales.

W. S. Little (*Associate Fellow*) formerly with the Shell Oil Company of Canada Ltd., Toronto, has been transferred to Shell International Petroleum Co. Ltd., Aviation Division, London.

A. F. Le Maistre (*Associate Fellow*) has been posted from the Structures Department, R.A.E., Farnborough, to Westland Aircraft Ltd., as R.T.O.

G. J. Malin (*Associate Fellow*) has been promoted to Assistant Director in the Directorate of Aircraft Production, Ministry of Aviation.

D. J. Maull (*Graduate*) formerly in the Aeronautical Department, Imperial College of Science and Technology, now holds the Senior Research Assistantship, Cambridge University Engineering Department.

Wing Cdr. G. Medd (*Associate*) formerly of R.A.F. Bassingbourne, has been appointed Command Mechanical Transport Officer at Headquarters Maintenance Command, Amport, Hants.

L. J. Murrin (*Associate Fellow*) formerly Assistant Project Engineer with the Curtiss Wright Corp., Caldwell, is now Principal Research and Development Engineer with Republic Aviation, Farmingdale, N.Y.

W. T. Neill (*Associate Fellow*) formerly with de Havilland Propellers Ltd., Lostock, has been appointed Managing Director of Platt Brothers and Co. Ltd., Hartford Works, Oldham.

Air Vice-Marshal W. A. Opie (*Fellow*) formerly Air Officer Commanding, R.A.F. Andover, has been appointed to the Board of Directors of Irwin Technical Ltd., London.

C. J. H. Peak (*Associate*) formerly a Senior Designer with the Installation Department, de Havilland Engine Co., Edgware, is now Assistant Design Engineer with the Weapons Research Division of A. V. Roe and Co. at Kingston.

W. E. W. Petter (*Fellow*) formerly Managing Director and Chief Engineer, Folland Aircraft, has been appointed a consultant to Hawker Siddeley Aviation.

J. Poole (*Associate Fellow*) formerly Head of the High Supersonic Speed Tunnel at R.A.E., Bedford, is now Superintendent of the Airborne and Helicopter Division of the Aeroplane and Armament Experimental Establishment, Ministry of Aviation, Boscombe Down.

Flt. Lt. D. C. D. Potter (*Graduate*) formerly carrying

out Work Study Duties at H.Q. Technical Training Command, has been posted to R.A.F., Driffield, for ballistic missile duties.

T. H. POWELL (*Associate Fellow*) formerly in the Ramjet Department, Bristol Siddeley Engines, is now a Senior Engineer, Aeronautics Division, Wiancko Engineering Co. in Pasadena.

RALPH J. QUARTON (*Student*) formerly with the de Havilland Aircraft Company, is now teaching Mathematics and Physics at Langley School, Langley Park, Norwich.

Flying Officer J. RAINE (*Student*) formerly an Engineering Officer (Aeronautical) R.C.A.F., Aylmer, Ontario, is now an Aircraft Repair Officer at R.C.A.F. Station, Moose Jaw, Saskatchewan, Canada.

Cmdr. C. RAWDEN (*Associate Fellow*) formerly Air Engineer Officer, R.N., is now Work Study Officer on the Staff of the General Manager, H.M. Dockyard, Chatham.

CHRISTOPHER J. ROGERS (*Associate Fellow*) formerly Sales Engineer, Automotive Products Company Ltd., is now Technical Sales Representative, London Sales Office, Centrax Ltd.

S. K. SAHIAR (*Graduate*) formerly a Stressman with Folland Aircraft Ltd., is now Technical Engineer, Bristol Aircraft Ltd., Weston Division.

J. L. SELLARS (*Graduate*) has been released from his Graduate Apprenticeship with Blackburn Aircraft Ltd., to attend the Two Year Diploma Course at Cranfield.

T. R. SIMES (*Graduate*) formerly a Design Draughtsman, de Havilland Engine Co. Ltd., London, is now a Lecturer in Mechanical Engineering, Nottingham and District Technical College.

E. F. SIMMONDS (*Graduate*) formerly taking a Postgraduate course in Aircraft Production at Saunders-Roe Ltd., has joined the Graviner Manufacturing Co. Ltd., Colnbrook, as an Installation Engineer.

P. SIMPKIN (*Associate Fellow*) formerly a Senior Aerodynamicist, de Havilland Aircraft Co. Ltd., Christchurch, is now an Aircraft Performance Engineer, Rolls-Royce Ltd., Derby.

Sqdn. Ldr. C. F. SLOPER (*Associate Fellow*) formerly at R.A.F. Halton, is now in the Armament Research and Development Establishment, Fort Halstead.

T. A. SMITH (*Associate Fellow*) formerly Leading Draughtsman, Design and Development of Solid and Liquid Propellant Rocket Motors, R.A.E., Westcott, is now an Engineer with the United Kingdom Atomic Engineering Authority.

TUDOR SPRINKS (*Student*) formerly Scientific Officer, Aerodynamics Department, R.A.E., Bedford, is now Research Assistant in Hypersonics at Southampton University.

Wing Cdr. H. P. STAPLEFORD (*Associate Fellow*) formerly at R.A.F. Manby, is now Officer Commanding Technical Wing, R.A.F. Geilenkirchen, Germany.

J. A. STAUNTON (*Associate Fellow*) formerly with the Ministry of Supply is now an Airworthiness Engineer, Advanced Projects Group, Hawker Siddeley Aviation Ltd.

Flt. Lt. C. G. STOCKER (*Associate Fellow*) formerly at the Ministry of Supply, Chessington, is now a Production Engineer at the Admiralty, Surface Weapons Establishment, Portsdown.

G. W. SUGGETT (*Associate Fellow*) formerly R.T.O. at the Ministry of Supply, is now in the Naval Aircraft Department of the R.A.E., Bedford.

H. P. SULLIVAN (*Associate Fellow*) formerly Superintendent, Experimental Engine Test Department, Rolls-Royce Ltd., is now a Management Consultant, Associated Industrial Consultants Ltd.

A. F. THOMAS (*Associate Fellow*) formerly R.T.O.(A), Dunlop Rubber Co. Ltd., is now Deputy Engineer, Aircraft Services Section, R.A.E., Bedford.

THOMAS THORNTON (*Associate Fellow*) formerly a Senior Technician with the Fairey Aviation Company, is now a Structures Engineer, Convair Aircraft Company, San Diego.

E. W. TROMAN (*Associate Fellow*) formerly Design Engineer, Avro Aircraft Ltd., Canada, is now Project Engineer, B. H. Hadley Inc., Cryogenic Engineers, Pomona, California, U.S.A.

I. K. TRUNDLEY (*Graduate*) formerly a Guided Missile Fitter, R.A.F., Henlow, is now an Engineer, Systems Laboratory (Research and Development Department), Kelvin and Hughes Ltd., Basingstoke.

Air Cdre. C. A. TURNER (*Associate Fellow*) formerly with the Air Department, Wellington, is now at Headquarters, Royal New Zealand Air Force, London.

G. W. UNDERWOOD (*Associate Fellow*) formerly Deputy Chief Research Engineer, Gloster Aircraft Co. Ltd., is now with the Advanced Projects Group, Hawker Siddeley Aviation Ltd.

T. V. VAREED (*Associate Fellow*) formerly a Senior Technical Engineer with Bristol Aero Engines Ltd., is now Chief Draughtsman in charge of the Department of Engine Design and Development, Hindustan Aircraft Ltd., Bangalore.

Dr. H. M. WADIA (*Associate Fellow*) formerly Chief Engineer, Indian Airlines Corporation, Bombay, is now Area Manager for the same firm in Calcutta.

J. H. WALMSLEY (*Associate Fellow*) formerly with Western Manufacturing (Reading) Ltd., is now Senior Designer, Teddington Aircraft Controls Ltd., Merthyr Tydfil, Glamorgan.

F. M. WARNER (*Associate*) formerly a Senior Development Engineer, G. W. Department, de Havilland Propellers Ltd., Hatfield, has been appointed a missionary of the Church Missionary Society to work at the Robert Money Technical High School, Bombay.

J. P. WHITWORTH (*Associate Fellow*) has relinquished his Commission in the Royal Air Force and rejoined Vickers-Armstrongs (Aircraft) Ltd., Weybridge, on the Military Project Design Staff.

ALAN WILSON (*Associate Fellow*) formerly Resident Technical Officer, Blackburn Aircraft Ltd., is now R.T.O. at Saunders-Roe, Helicopter Division, Southampton.

A. A. WOODFIELD (*Student*) on graduating from Imperial College has been appointed a Scientific Officer, Aero Flight Division, Royal Aircraft Establishment, Bedford.

Professor L. C. WOODS (*Associate Fellow*) formerly at the School of Mechanical Engineering, University of New South Wales, will be at the A.E.R.E., Harwell, until January 1961.

PETER M. WRIGHT (*Associate Fellow*) formerly Sales Executive, High Duty Alloys Ltd., is now Manager, J. H. Little (Traction) Ltd., London.

ALAN L. YETTRAM (*Graduate*) formerly a Research Assistant in the Aeronautics Department of Imperial College has now been appointed to the newly created Lectureship in Aircraft Structures in the Department of Civil Engineering at the University of Leeds.

Summaries of Lectures

MAGNETOGASDYNAMICS

by

DR. J. A. SHERCLIFF
(*Lecturer in the Department of Engineering Cambridge*)

Given on 17th November 1959

The lecture was a survey of magnetogasdynamics. The governing equations and their validity were discussed first, then one-dimensional problems were treated for the very different cases of high and low magnetic Reynolds number. Steepening of compressive waves and shock structure were topics included in this section. Finally, two-dimensional steady flows at high magnetic Reynolds number were discussed.

HEAT AND MASS TRANSFER IN AERONAUTICAL ENGINEERING

by

D. B. SPALDING
(*Imperial College*)

Given on 24th November 1959

The main purpose of the lecture was to show that standard techniques of heat and mass transfer theory, as practised in other branches of engineering, could be helpfully applied to the corresponding aeronautical problems, particularly those arising in connection with high-speed flight and rocket propulsion.

After a brief outline of the main features of the theory of heat and mass transfer in chemically reacting fluids, the standard techniques were applied to the following problems:—

(*a*) *The laminar boundary layer at the nose of an axi-symmetrical body at hypersonic flight speed.*

- (*i*) How to calculate the heat transfer rate to an internally cooled surface, taking account of dissociation.
- (*ii*) How to calculate the quantity of coolant needed for transpiration-cooling of the surface, taking account of possible combustion of the coolant.
- (*iii*) How to calculate the rate of burning of a graphite "heat-shield."
- (*iv*) How to calculate the rate of "ablation" of a heat-shield material which melts and sublimes.

(*b*) *The turbulent boundary layer in the nozzle of a rocket motor.*

- (*i*) How to calculate the heat flow from the gas to a bare metal nozzle wall:— simple formula; pipe-flow formula; boundary layer analysis.
- (*ii*) How to calculate the rate of supply of liquid fuel to the motor wall if film-cooling is to be employed.
- (*iii*) How to estimate the thickness of carbon film which will be deposited on the wall of a liquid-oxygen-kerosine motor, and its influence on the heat transfer rate.
- (*iv*) How to calculate the rate of enlargement of the throat area of a solid-propellant rocket motor with a graphite nozzle.

The procedures used comprised the following elements:—

(*a*) Relations of the Ohm's Law type, namely:
"*Mass transfer rate per unit area* = *surface conductance, g, times dimensionless driving force, B.*"
and, in the absence of mass transfer
"*Heat transfer rate per unit area* = *g times enthalpy difference.*"

(*b*) Aerodynamic analysis leading to evaluation of the conductance *g*, in lb./ft.²h. Boundary layer theory is used.

(*c*) Thermodynamic analysis leading to the evaluation of *B* or of the enthalpy difference. Here diagrams of the enthalpy of the occurrent mixture versus its composition are used, permitting graphical evaluation of the required quantities.

Note—This lecture will be published in either the JOURNAL or the AERONAUTICAL QUARTERLY.

Man Powered Aircraft Group

MAN AS AN AERO ENGINE

by

DR. D. R. WILKIE
(*University College*)

Given on 27th November 1959

Muscles are machines for converting chemical energy into mechanical work, and the power production of the body is limited ultimately by the rate at which this conversion can be performed. The ultimate source of the chemical energy is the oxidation of food materials, especially carbohydrates, in the muscles. For this purpose, oxygen must be transported via the lungs and the circulating blood, and it is the limited capacity of this transport system that limits the continuous power rating of the body to 0·4–0·5 h.p. However, a limited amount of energy can also be obtained by hydrolysis of various compounds within the muscles, and these reactions are not limited by O_2 supply. Thus, during a short effort (less than about 5 minutes), the power output of the body may be considerably greater than its steady state level, *e.g.* 0·9 h.p. maintained for 1 minute, or 3 h.p. for about 1 second.

A comparison between animals and petrol engines shows that the animals have rather unfavourable power/weight ratios and the disadvantage is greater with large animals, such as men, than with small ones.

The question of the power *required* to fly is essentially one that needs detailed aerodynamic solution. However, generalised dimensional arguments based on a comparison between birds and man do indicate that flight by manpower should be just possible.

TRANSONIC FLOW OVER SWEPT WINGS

by

E. W. W. ROGERS and Dr I. M. HALL
(*Aerodynamics Division, N.P.L.*)

Given on 1st December 1959

The lecture discussed the development of the flow about plane, finite swept-back wings, having leading edge sweeps of about 50°, as the stream speed is increased from subsonic to supersonic values. Shock waves appear in conditions which would not be expected from simple swept-back theory and these can be shown to be due in large measure to the three-dimensional nature of the flow. The effect of the flow development on the overall wing forces and moments was considered and a brief discussion of the problems of shock-wave and boundary layer interaction was included.

SOME SERVO MECHANISMS FOR SUPERSONIC AIRCRAFT

by

S. G. GLAZE, B.Sc.
(*Performance Calculations Group, H. M. Hobson, Ltd.*)

Main Lecture at the Gloucester and Cheltenham Branch given at St. Mary's Hall, Cheltenham on 3rd December 1959

This paper discusses the need for new and improved control systems on board supersonic aircraft and relates these to the rise in ambient temperature and the requirement of high overall propulsive efficiency. The opportunity to benefit from experience is also seen to affect the current trend in system thinking. Consideration of the duties required of these systems

in a wide range of conditions is shown to be facilitated by analogue methods of study. Theoretical treatment alone is inadequate. Rejection of non-linear apparatus in the past is claimed to have resulted from conditions which either no longer apply, or need reappraisal. Two present deficiencies in analogue treatment of problems are discussed.

Some servo-mechanisms which are aimed at improving overall propulsive efficiency and combating the other problems of supersonic flight, are described by way of example. These include pneumatic fuel system components, variable geometry intake control systems for shock wave positioning; ways in which the centre of gravity of the fuel load may be controlled, or moved, in flight; a variable geometry convergent/divergent exit nozzle for maintaining engine turbine pressure ratio, and recovering maximum propulsive effect from a reheat system; and finally a system of information transmission to the main control surfaces by electrical means which is fundamentally fail safe, enables weight to be saved, and automatic flight control systems to be rationalised.

The reasons for incorporating these mechanisms in the aircraft are given and their functions and method of operation are discussed. Particular difficulties arising from the individual solutions of these problems are given from the servo engineers viewpoint including the important non-linearities.

It is concluded that in the future, as in the past, systems of increasing complexity will be studied by ever improving methods, and that it is necessary that they should be so studied. It is unlikely that the new systems are entirely untried, since some of the components are already in use. A greater experimental effort is desirable to support the theoretical work required.

SOME PRACTICAL ASPECTS OF COMPRESSOR BLADE VIBRATION

by

E. K. ARMSTRONG, Ph.D.
(Vibration Engineer, Bristol Siddeley Engines)

and

R. E. STEVENSON, M.Sc.
(Head of Compressor Department, Bristol Siddeley Engines)

Given on 8th December 1959

One of the principal criticisms that can be levelled against the modern gas turbine engine is that the axial flow compressor is susceptible to complete blade failure caused by the fatigue of one blade. The initial failure being due to vibration at large amplitude.

The results of testing of single stage research compressors, backed by engine experience indicates that there are four causes of blade vibration, namely:

(*a*) Resonance, *i.e.* with intake or outlet casing struts
(*b*) Flutter, resulting from blade stall or choking
(*c*) Stall cell rotation
(*d*) Random excitation, possibly relating to intake flow disturbances.

Where the resultant amplitudes are large it is obviously essential to be able to modify the engine to reduce the amplitudes to an acceptable level. These solutions must be capable of being introduced quickly to minimise engine development cost. If at all possible they must also avoid any major design change to the engine scantlings and any significant mal-effect to engine performance. Once an apparent solution is determined it must be "proved" and this may demand special motorised throttle tests and artificial devices aimed at stimulating aircraft installation and flight operation. Finally, if the full benefit is to be gained from this experience a detailed understanding of the fundamental reasons for the various modifications involved must be available. With this knowledge, appropriate design rules can then be formulated for new designs.

To accomplish this it is necessary to make strictly comparative engine compressor blade strain gauge tests. It is found that many engine parameters effect the blade amplitude, *e.g.* engine nozzle size, turbine stator throat area (affecting engine operating line on compressor characteristic), air bleeds, compressor construction and engine installation.

From the character of the blade strain gauge signals it is necessary to be able to identify the class of the vibration which is present. It is found that this can be done. To obtain a more detailed description of the vibration, hot wire anemometer tests and special engine tests may be carried out.

By analysing development test experience it is possible to illustrate how the amplitudes of vibration of most of the classes of vibration are influenced by parameters of the following type; intake conditions, blade material, blade mechanical damping, aerodynamic environment, *i.e.* incidence, blade frequency. This experience indicates the solutions which are to be most satisfactory for a given problem.

The type of variation in amplitude with the above parameters is compared with that predicted by some of the simplified theories which have been developed in connection with compressor blade vibration.

In order to anticipate whether an engine modification reduces the amplitudes sufficiently, an estimate of the blade life should be made. The major difficulties in carrying out this prediction are considered to be variation of amplitude, presence of more than one mode, knowledge of the flight plan of aircraft, scatter in amplitudes between blades and engines.

ALL DAY DISCUSSION ON FLIGHT SAFETY Four Papers

Held on 11th December 1959

THE OPERATOR'S VIEW

by

Captain J. W. G. JAMES
(B.E.A.)

The Relativity of Safety. No absolute standard, especially when human element is involved. Human error factor of growing importance. Need for parallel development of man and machine.

Co-operation with manufacturer to produce an aircraft that is not "accident prone." Need for integrated design covering all aspects including communications and radio aids.

The aircraft and its environment—control of air space. Crew training—how should standard be specified? Has there been too much concentration on manual dexterity? Monitoring and cockpit management. Checking, base and route; use of Flight Simulators.

Information channels. Instructions and bulletins. Exchange of information between operators and manufacturers. Safety propaganda—seasonal weather problem. The relationship between the State and the operator—delegation of authority—international legislation.

THE AIRLINE PILOT'S VIEW

by

Captain E. C. MILES
(B.O.A.C.)

In addition to his normal concern for flight safety when in the air, the airline pilot is now participating in the formation of safety regulations. He is learning that his view, that safety is sacrosanct, is not shared by all of the Industry. This other

view, that satisfactory safety is achieved by balancing the probabilities of accidents against the economics of accident avoidance, is not acceptable to the airline pilot. The two views are examined. An additional application of the probability concept is based on the assumption that the accident record is satisfactory. The record needs to be re-examined to see if this assumption is warranted. Some of the flight safety danger areas are examined.

THE ACCIDENT INVESTIGATOR'S VIEW

by

P. G. TWEEDIE, O.B.E.
(Chief Inspector, Accident Investigation Branch, Ministry of Aviation)

The relationship between accidents investigation and air safety and what may be involved in the investigation of a big accident is considered briefly.

Consideration is given as to whether, in the light of present and future technical trends, the causes of accidents can be ascertained precisely enough to enable remedial measures to be taken. The trends are against the investigator and his task is becoming increasingly difficult. While recognising the complex problems involved, ways in which the investigator could be assisted in his task are suggested. Since a serious accident to any new and large aircraft is a disaster which can have the widest repercussions, the paper suggests that manufacturers and operators should build and instal into an aircraft as many means as it may be possible to devise which will assist in the investigation of any accident in which the aircraft may be involved.

THE AIRCRAFT CONSTRUCTORS' PROBLEMS

by

R. H. WARDE
(Bristol Aircraft Ltd.)

Flight Safety is a subject which ranges beyond the control of the aircraft constructor. While it should be the natural aim of the constructor to see that the aircraft matches the highest standards of safety, his control over the safety in flight in the hands of the operator is limited. The aim of this paper is to examine in a broad manner the extent to which the aircraft constructor can contribute towards Flight Safety and to suggest some methods to improve the overall safety level by a better understanding of the problems.

A general examination of the subject requires, first a definition of the term "Flight Safety," followed by an investigation of the constructors' responsibilities and human factor problems within the Design Organisation. There is a fairly wide gulf between the outlook and attitude to this problem as seen by the constructors' technical staff and those responsible for carrying on the business of regular passenger-carrying flights.

Of great importance to Flight Safety is the matching of the Design Specification with the Operator's Requirements, especially when several operators become prospective customers. This is followed by the jigsaw puzzle of fitting the Design to the Airworthiness and Design Safety Requirements.

The above are only the beginning of the constructors' problems as the next phase covers the proving, to the satisfaction of all concerned, that the operational and design safety standards have in fact been met. This phase can make a major contribution to Flight Safety.

Finally, examination is made of possible ways to improve Flight Safety by a properly co-ordinated effort between the constructor and operator throughout the passenger-carrying life of the aircraft.

DESIGN FEATURES OF REAR ENGINE INSTALLATIONS FOR TRANSPORT AIRCRAFT

by

E. S. ALLWRIGHT

To be given on 17th December 1959

A statement is made of the benefits which arise in jet-engined transports in which the engines are installed at the tail. Many aspects of this arrangement are considered in the paper with particular interest in the engineering design and the effect on aircraft systems and airworthiness. Special attention is given to the possible results of engine failures. Safety during crash landings and ditching is also discussed.

Examples of design features incorporated on the Vickers V.C.10 are taken to illustrate the lecture.

YOUNG PEOPLE'S LECTURE

FLYING VERSUS THE HUMAN MACHINE

(A Lecture Demonstration on some Human Problems in High Performance Flight)

by

Dr. G. MELVILL JONES

To be given on 7th January 1960

Living things, generally speaking, are highly specialised to function within the surroundings in which they have evolved and even small changes in these surroundings can quickly lead to serious and often unexpected deficiencies in their working mechanisms. Man, perhaps the most specialist of all living creatures, is no exception. And since, in high performance flight today, he is hurled into a new world of low atmospheric pressure, great speed, high acceleration, extremes of temperature and a somewhat eerie remoteness from the earth's surface, it is not to be wondered at that problems arise which tax his ingenuity to the utmost.

In this Lecture, some of these problems, and the ways in which they have been, and are being, solved, will be traced, with the aid of slides, film and demonstration, through the story of flying, from early days of ballooning to the present era of supersonic flight. When man is projected beyond the atmosphere, this exciting story will have to extend still further, and the lecture will also include a brief glance at some of the human problems which will then arise, as they now appear in the light of those with which we have already had to contend.

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CLAUDE GRAHAME-WHITE

1879 - 1959

CLAUDE GRAHAME-WHITE, who died on 19th August 1959, in Nice, after a short illness, was perhaps the outstanding British pilot in those golden years of flying 1909-1914. He did more than anyone to stimulate interest in flying in those early days and, in the 1916 edition of the then well-known "Representative Subjects of the King" published by Dod's Peerage Publishers, was described as "a pioneer of aviation, not only as an aeroplane pilot but as a constructor, and one of the chief originators of this new Industry in England—an industry which now promises to equalise in importance, and eventually eclipse, even such a great industry as that of shipbuilding".

Born in Bursledon, Hants on the 21st August 1879, he was educated at Crondall House School, Surrey, and Bedford Grammar School and gave evidence of remarkable mechanical talent at an early age.

After leaving school he spent some years in Yorkshire at a mill belonging to one of his uncles, acquiring a business training before coming South. During these years he took an intense and practical interest in the development of motoring but in 1909 turned his energies to heavier-than-air machines, learning to fly at the Blériot School at Issy-les-Moulineaux (now Paris heliport). He was awarded an Aviator's Certificate by the Aero Club de France in December 1909 and on 26th April 1910 was awarded the Royal Aero Club's Certificate No. 6.

In 1909 he established a British Flying School at Pau but returned to England the following year, establishing his school at Brooklands. In that year, 1910 he was the principal attraction at the British flying meetings at Bournemouth, Blackpool, and Wolverhampton and the name "Grahame-White" became a household word after his stirring contest with Louis Paulhan for the "Daily Mail" London to Manchester Prize of £10,000. Although he lost that event his outstanding performance, which included a daring night flight, created world-wide attention and won for him the Gold Medal of the French Aero Club. The story of the London-Manchester Race has been told many times and is one of the epic stories of the early days of flying.

Subsequently Grahame-White made an extensive tour round England to stimulate interest in aviation and in September 1910, went to the United States of America, taking part in many aviation meetings and winning a great deal of prize money and prizes, including the Gordon Bennett Challenge Cup for the international speed race at Belmont Park, which he won at about 60 m.p.h. in a Blériot. It was during this American tour that he landed on Executive Avenue, in front of the White House, to visit President Taft.

Claude Grahame-White

On his return from America Grahame-White acquired the tract of land at Hendon, known as "London Aerodrome" and founded the Grahame-White Aviation Company Limited. Here, in addition to training many pilots, including naval and military officers, he built aeroplanes, among them the well-known Grahame-White "Baby" and the "Charabanc" which established a world's record carrying nine passengers in 1913.

From 1911 to the outbreak of war in 1914 Grahame-White organised flying meetings, races such as the Aerial Derby, Circuit of Britain, and exhibitions, summer and winter alike, in which the foremost aviators of the day took part and which attracted crowds on some occasions of over 60,000. During 1913 fifty-one aerial race meetings were held at Hendon and, in addition, there were two aerial fetes, eleven demonstrations of upside-down flying and looping and, five illuminated night-flying exhibitions which included realistic demonstrations of aerial warfare, such as bombing a set piece—believed to be the first of their kind ever organised.

On 12th May 1911, Grahame-White organised at Hendon, under the auspices of the Parliamentary Aerial Defence Committee, a military flying display which was attended by the Duke and Duchess of Connaught, leading Ministers of the Crown and members of Parliament. A few days earlier he had addressed the Committee at the Houses of Parliament on the necessity of developing military aircraft.

He also demonstrated the commercial possibilities of aircraft, the first aerial post of the United Kingdom being carried in 1911 between Hendon and Windsor with the sanction of the Postmaster General, by pilots of the Grahame-White Aviation Company.

On the outbreak of war in 1914 Grahame-White joined the R.N.A.S. in the then rank of Flight Commander. He took part in a number of raids on enemy bases but in 1915 relinquished his commission, with the approval of the Admiralty, to devote his energies to his work at Hendon where his company was building military aircraft and training large numbers of pilots for the two services.

After the war Hendon again became the scene of many flying meetings and displays, including once more the Aerial Derby, but in 1925 Grahame-White sold Hendon to the Air Ministry and gave up his active participation in aviation, although he never entirely lost his interest in it. He devoted himself to property business in Europe and America and in later years lived much of the time abroad.

Claude Grahame-White was indeed a pioneer of British aviation. Although never an active member of the Society he had been a Companion since 1912 and lectured to the Society in 1919 on "Commercial and Pleasure Flying", a lecture in which he stressed the need for safety and regularity in bad weather, advocated a system of lighting for landings in fog and looked forward to the day when no part of the "earth's surface, however remote, is more than a week's journey from London by air".

When the Society holds its Anniversary Luncheon on 12th January 1960, to celebrate both its 94th Anniversary and the Golden Jubilee of that Golden Year in British Aviation, 1910, Claude Grahame-White will be specially remembered; as one of the pioneers and one of the outstanding figures of that year, it had been hoped that he would be present.

One of his oldest surviving friends in aviation, Harry Harper, has contributed the following reminiscences:

I was sitting in "The Daily Mail" office on an evening early in April 1910, when I was called to the telephone by Harold Perrin, Secretary of the Aero Club.

"I've an entrant here for your London-Manchester prize who really means business," he said. "You had better come over."

This was good news for me, as previous entries had shown a disappointing habit of fizzling out.

On arrival at the Club, Perrin introduced me to a tall, dark, athletic-looking young man, whose keen-featured face and swift, decisive way of speaking and moving seemed to radiate such an irresistibly dynamic energy as I do not think I have ever encountered, to quite the same extent, in any man before or since. That was my first meeting with Claude Grahame-White. His entry into aviation was proof enough of this truly amazing energy. After building models of a helicopter type, and after making a good many balloon trips, at the time Blériot flew the Channel, he was buying and selling motor cars from an office in Albemarle Street.

It was Blériot's triumph which made him dash across to France to be present at the world's first air meeting at Rheims which followed closely on the Channel flights, his idea being to buy a monoplane from Blériot and learn to fly it as quickly as possible.

It was typical of his determination to overcome any obstacle that might lie in his path that, finding it impossible at first to obtain any card admitting him to the closely-guarded pilots' enclosure, he managed to mingle adroitly with an official party which had come down from Paris and, speaking French fluently, as he did, was able to slip in with them without being challenged. Once inside, he lost no time in offering to buy, immediately the meeting ended, the bigger type of 2-seater 50 h.p. monoplane which Blériot was flying for the first time at Rheims. But, as it happened, Blériot crashed this particular machine while taking part in the speed contest at Rheims. He offered, however, to build Grahame-White a replica in his Paris factory. At this Claude asked permission—which was rather reluctantly granted by Blériot—to work in the factory himself on the construction of this machine, clocking in at 6.30 a.m. each morning like any of the other men. So it was that for three months Claude helped to build his own machine, gaining thereby a knowledge of pioneer aeroplane construction which was to prove invaluable to him later on.

No better illustration of this young man's astonishing courage and determination could be found than if one recalls that morning out at Issy when he took delivery of the monoplane he had helped to build, and which he had christened "White Eagle."

Some of Blériot's mechanics had promised to come out and help him do a little preliminary taxying. But time passed and they did not appear. Whereupon Claude and the friend who was with him, Capt. Fleetwood Wilson, wheeled the machine out of its shed and tethered it with a rope to some nearby railings. Then Claude swung the airscrew. The engine, to their surprise, began firing at once. But as they had forgotten to take up the slack of the rope, the monoplane lurched forward and knocked Claude flat on his back. Undeterred, he sprang to his feet, shouting to his friend to cast off the rope and jump into the passenger's seat before the machine was moving too fast for him to do so. This Fleetwood Wilson just managed to do, and soon they were taxying here and there across the aerodrome.

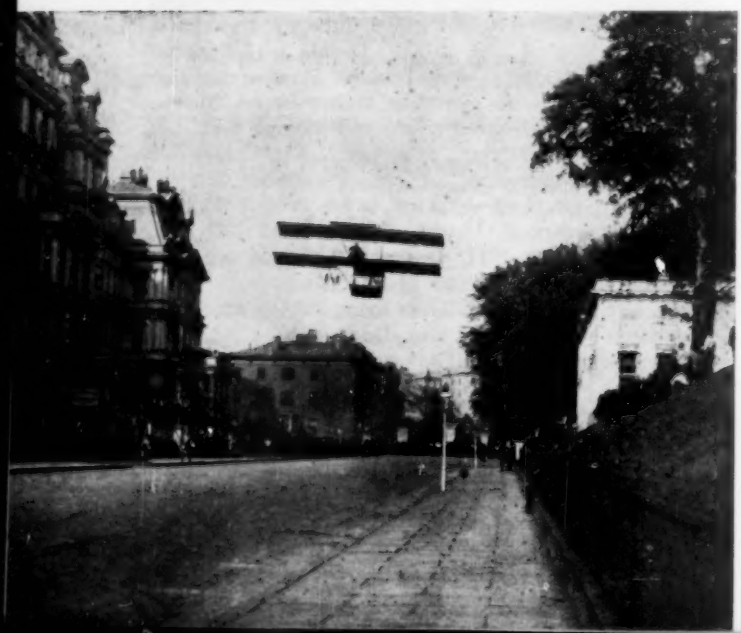
Before long this became too tame for Claude. Turning to his friend with a grin, he shouted above the roar of the engine:

"Hold on tight. I'm going to try a hop."

Fleetwood Wilson said afterwards that remembering Grahame-White had only been at the controls of the machine for a matter of minutes, the idea of actual flying seemed to him little short of suicidal, and he could not make up his mind whether to throw himself out of the machine, while it was still on the ground, or just sit where he was and hope for the best. He did the latter.

Giving the engine a little more throttle, Claude drew back cautiously on the elevator lever, and a moment later they were flying! Never, afterwards, did Claude forget that thrill of taking an aeroplane off the ground for the first time.

When he glanced down, as he told me afterwards, he felt a moment of some alarm at seeing the ground receding below them much more rapidly than he had expected. But another movement of throttle and control lever, not too abruptly



Mr. Grahame-White landing in front of The White House in 1910 to call on President Taft.

made, brought the monoplane's wheels back on the ground again without the slightest shock or jar. And soon he was making higher and longer hops.

It was then that the tardy mechanics arrived, staring in amazement when they saw Claude flying towards them. And in the Paris newspapers next morning there were lurid stories of how this "mad Englishman," Grahame-White, had learned to fly in 20 minutes.

At Blériot's suggestion Grahame-White transferred the "White Eagle" to the flying-ground at Pau, where flying conditions were more favourable. But then an odd thing happened. Coming down to Pau from Paris, Blériot offered to take Claude's monoplane up for a test flight, with Claude himself as passenger. That day even this great man was guilty of an error in pilotage. Finding himself too near some trees, he attempted such an abrupt turning movement that they got into a spin and the monoplane crashed so badly that it was a write-off. Neither of its occupants were hurt.

Blériot offered Claude two of the smaller cross-Channel type monoplanes for the wrecked machine, and it was with these two machines that Claude started at Pau a pioneer British flying school. It was here, too, in one of these machines, that in December 1909, Grahame-White made all the necessary flights to obtain an official aeroplane pilot's ticket—being the first Englishman to do so after Henri Farman.

A prelude to one of the greatest of our early air epics came on a day when Grahame-White rang me from Paris. He said he had just learned that the redoubtable Louis Paulhan, who had been flying in America, was coming back to make an attempt to win the £10,000 London-Manchester prize. But, said Claude, he had no intention of allowing the little Frenchman to be first in the field, and was going to have a try himself just as soon as he could get things organised. He added that in his opinion the best machine for the job was the 50 h.p. Gnome-engined Farman biplane such as Farman himself had been flying at Rheims.

Within the next few days Claude contrived not only to buy a Farman biplane but also, after only a few preliminary flights at Mourmelon, to stay up for an hour to familiarise himself thoroughly with the handling of the machine. Then he had it shipped to England, and in that never-to-be forgotten month of April 1910, we found ourselves turning pages of pioneer air history with almost bewildering speed. The story of those London-Manchester flights has been told time and again and in full detail and my chief aim is to paint a pen-picture of Grahame-White as I knew him personally in our golden age of the air.

It was on 21st April, hastening his last-minute preparations, when it became known that Paulhan had crated his biplane on a liner leaving New York and was already on his way home, that Grahame-White took off from Park Royal on his first attempt to fly to Manchester. In a big White steam car, driven by that steam-car expert Freddy Coleman, I followed the aeroplane as it flew north above the railway towards its first refuelling point in a field near Rugby.

When I reached the spot I found Claude warming himself in a neighbouring cottage. He told me he had felt the cold terribly, sitting out forward on his unprotected pilot's seat. Once, in fact, while over Bletchley, he had become so numb he was afraid he might lose control over his machine. Fortunately, in a pocket of his flying suit, he had a small flask of brandy with its stopper unfastened. A nip of this brandy, together with some chocolate, had warmed him sufficiently to enable him to carry on.

The sheds and enclosures at the London Aerodrome, Hendon, during one of the early race meetings.

That 83 miles to Rugby was not only Claude's first cross-country flight, but it was also the first cross-country aeroplane flight to be made in England.

When he left Rugby, en route for Manchester, with only another 93 miles to fly, we all felt that the prize was within his grasp. But heavy wind gusts, and valve trouble with his Gnome, brought him down at Hademore Crossing, near Lichfield.

Hot on the trail in my big steamer, I found Claude resting in an hotel at Lichfield while mechanics worked on his engine. But hardly had I arrived when a car came dashing up with some very bad news indeed. A heavy gust of wind had overturned Claude's biplane as it stood out in a field, and the machine had been badly damaged. With no reserve machine and Paulhan well on the way the outlook looked bad indeed.

But now I saw Claude really go into top gear. After dashing out to the field to examine the damage to his machine, he raced back to the hotel, and began making urgent telephone calls. From the railway company he conjured up a special train with a long scenery van big enough to accommodate the wings and fuselage of the aeroplane. And he also managed to arrange that, when his damaged machine reached London, it could be sent to the airship shed at Wormwood Scrubs. In this shed, working with his mechanics day and night, he hoped to repair the machine soon enough to be ready for another London-Manchester attempt before Paulhan could arrive on the scene.

But the repairs took longer than he had calculated and it was not until the morning of 27th April that the biplane was ready for flight; by that time Paulhan was definitely in the running, having established his camp in a field at Hendon, and being ready to start for Manchester as soon as weather conditions were favourable.

That morning, however, there was a high and gusty wind and, flying being out of the question for the moment, Claude decided to drive over to Hendon for a chat with Paulhan. I went with him, and the two rivals had a friendly talk. Henri Farman was with Paulhan, and it was agreed that, to make a sporting affair of it, the two flyers should arrange that both of them started off for Manchester at approximately the same time.

After lunch in an hotel at Wormwood Scrubs, Claude went upstairs for a short rest, being worn out by all the day-and-night work on the biplane repairs. The wind seemed to be moderating a little, and I was making my way over to the

Ready for flight in a Farman, at Ranelagh.

Photograph by F. N. Birkett

airship shed when a car came dashing up from Hendon with the news that, after a short test flight, Paulhan had actually started for Manchester at 5.31 p.m.

Farman told me afterwards that, as had been arranged, instructions had been given for Claude to be notified that, with wind conditions now improving, Paulhan had made up his mind to start. For some reason or other, which we could never ascertain, that message never got through, and the first news Claude had that Paulhan was in the air was when someone ran up to his hotel bedroom to tell him.

The next thing I remember was seeing him rushing across from the hotel to the airship shed, buttoning up his flying coat as he ran, but it was not until 6.29 p.m. that he was able to take off. And, with an hour's less daylight than Paulhan, he found himself compelled by gathering darkness to alight in a field near the railway at Roade, 60 miles only from his starting-point, whereas Paulhan had got as far as Lichfield, 117 miles on his flight to Manchester.

When Coleman and I steamed into Roade we found Claude in the house of the local doctor, sitting down to a meal of bacon and eggs. With him was Roger Wallace, Chairman of the Aero Club, Harold Perrin, Secretary, and other Club members and officials.

The question was what was Claude to do next? If he waited till dawn it was obvious that Paulhan, profiting by the lead he had obtained, and barring accidents, would be first to reach Manchester and win that £10,000.

Claude himself solved the problem as he lit an after-supper cigarette. "There's only one thing to do," he said. "My only chance of overtaking Paulhan's lead is to make a night flight. I know it's never been done before. I realise well enough all the risk it implies, with the chance of engine failure and with no night-flying aids. But it's my only chance now, and I mean to take it."

Of course there were protests, but once Claude had made up his mind, nothing could dissuade him.

At 2.45 a.m. he took off from the field in which he had landed earlier—the first man to fly an aeroplane at night.

It was a dark night with just an occasional gleam of moonlight. His biplane had been drawn up at one end of the field, and motor car and bicycle head-lamps had been shone on the opposite hedge to help him judge his take-off. Holding his machine down as he gathered speed, he made a leap over that hedge like some giant spring-heeled Jack, and vanished into the darkness. As he climbed over Roade railway station he had, as he told me afterwards, a nerve-trying moment. His Gnome engine spluttered and threatened to stop. Fumbling among the controls, he found that his coat-sleeve must, without his knowing it, have switched off the ignition. A quick movement of the switch, and the engine opened up again.

Coleman and I had taken our steamer to some cross-roads five miles ahead, shining our head-lamps on the white-washed wall of an inn. This we hoped might act as a guide for Claude. Actually it did. Soon we heard a drone in the darkness of the sky, and then caught sight of what looked like a ring of fire flitting over some neighbouring fields. It was the exhaust from the Gnome. Claude came flying directly towards us, and for a few miles we acted as his guide, Coleman giving that big steamer all it would take. Then Claude caught sight of a goods train on the railway, and decided to follow that. He was flying so low that we could see him wave an arm to us as he turned away towards the railway.

The story after that has already been told many times. Claude continued to make night-flying history until vicious gusts in the notoriously windy Trent Valley forced him down at 4.14 a.m. at Polesworth, 10 miles short of the spot where Paulhan had landed the previous night. And Paulhan himself, rising at the first glimmer of light from Lichfield, managed to fight his way through the wind to Manchester and win the coveted £10,000.

Claude, although unsuccessful, none the less became England's first great public air hero, largely because of the sporting nature of his effort, and of the gallantry of his night flight, and also because here was an Englishman who, for the first time, could enter into competition with one of the great French champions in this new art of flying.

When he drove through the West-end people recognised and waved to him. He was impersonated in a popular revue, and joined the ranks of the famous among Madame Tussaud's waxworks.

It was in that summer of 1910 that Claude went over to America and, flying a racing Blériot with a 14-cylinder, 100-h.p. Gnome, won for Britain the Gordon Bennett speed race, defeating such champions as Latham, Aubrun, Brookins and Leblanc, and registering a speed of a fraction over 60 miles an hour.

It was in recognition of the distinction he had conferred on British aeronautics by winning this prize that Grahame-White was awarded the Gold Medal of the Royal Aero Club.

Meeting him on his return from America, he told me his chief ambition now was to establish a big popular flying ground as near as possible to London. With this in mind he motored here and there, looking for a possible site. One afternoon, when I was with him, we found ourselves at the top of Hendon Hill, near the old church, looking down across the hundreds of acres of flat pasture land that formed the valley north-west by the side of the railway. In a flash Claude decided that here, only a few miles from the heart of London, was the very spot he had been looking for. Whereupon he threw himself, with his usual enormous energy, into the task of creating what became the world-famed London Aerodrome, to which, before long, as many as 60,000 spectators would come to watch one of the Saturday afternoon flying displays.

Apart from the Aerial Derbies round London, which became such a popular feature of the Hendon programmes, one of the highlights I remember particularly was on 12th May, 1911, where, in collaboration with the Parliamentary Aerial Defence Committee, Grahame-White organised a special display—the first of its kind—at which the military potentialities of the aeroplane were demonstrated in aerial scouting, dispatch carrying and bomb-dropping, Claude himself dropping bags of flour which burst realistically on the dummy shape of a battleship which had been outlined on the aerodrome. Not only this, but Claude persuaded Mr. Balfour and Mr. McKenna, among others, to make short passenger flights with him.

With the coming of the First World War Claude immediately placed himself, and his entire organisation at Hendon, at the disposal of the authorities, he himself being given a commission as Flight-Commander for special service with the Royal Naval Air Service, and taking part personally in one of the first big air raids on enemy-held positions across the Channel. Piloting an 80-h.p. Farman he crossed the Channel only to be forced down into the sea, when about four miles from the Belgian coast off Nieuport, by a violent snow storm. Luckily for him his descent into the sea was observed by a French mine-sweeper, which picked him up and transferred him to a British gun-boat.

Soon after this, under the increasing pressure of his war work at Hendon, where he was not only building naval and military aeroplanes in constantly-growing numbers, but training in addition large batches of pilots for the two services, with the approval of the Admiralty he relinquished his Naval commission and devoted himself exclusively, for the remainder of the war, to these developments at Hendon.

The war over, Grahame-White switched his energies with unabated vigour to the commercial and pleasure aspects of aviation, establishing a pioneer flying club at Hendon, and encouraging in every way the private and pleasure use of aeroplanes. But from Claude's point of view, as he himself told me, and certainly also from mine, there was something sadly missing from those post-war years. We felt the romance was going out of flying. We felt that everything was becoming more and more commercialised. We yearned for that "golden age" of pioneer flying which vanished when the world went to war. Aviation moved into an era which was more and more technical, and in which science was replacing romance.

Apart from being a magnificent pilot, Claude was also a very successful business man, and he found himself more and more concerned with big property transactions both here and on the other side of the Atlantic. Presently he sold his famous Hendon aerodrome to the Air Ministry, and, although he still remained keenly interested in air progress, he took no further actual part in it.

To me, now-a-days, whenever I think of him, one imperishable memory always comes into my mind. It is of that night at Roade, away back now just on 50 years, when he taxied away resolutely and flew up into the darkness to face all the perils of the world's first aeroplane flight at night.

OPERATIONAL PROBLEMS OF TAKE-OFF AND LANDING

A Symposium on "Operational Problems of Take-Off and Landing" was held under the auspices of the Society, with Mr. Peter G. Masefield, M.A., M.Inst.T., Hon.F.I.A.S., F.R.Ae.S., President of the Society as Chairman, on 4th September 1959, in the Library at 4 Hamilton Place. The Symposium was held in conjunction with the Sixth Meeting of the Commonwealth Advisory Aeronautical Research Council which was held in London in September.

Introductory papers were given by Mr. E. W. Pike, A.F.R.Ae.S., Captain B. O. Prowse, Mr. L. P. Coombes, D.F.C., B.Sc., F.R.Ae.S. and Mr. E. S. Calvert, A.R.C.Sc.I., B.Sc. and the Discussion was in two parts—after the second paper and after the fourth. The Discussion was recorded and was prepared for publication by Mr. R. W. Gandy and Group Captain R. B. Harrison, Secretary and Assistant Secretary respectively of the C.A.A.R.C.

Two additional papers from the Commonwealth had been prepared for the Symposium, but were unable to be given because of lack of time; they are given here as an Appendix.

Mr. Peter Masefield (*The Chairman*), introducing the lecturers said that Mr. Pike was well-known not only to people in this country but in others, because he had been concerned with operational problems for a long time. He was today Head of the Air Traffic Control Development Unit of Air Trainers Link Ltd., a post which he had recently taken up on leaving his former position as Deputy Flight Manager of B.O.A.C., and they wished him great success and happiness in his new post. Mr. Pike, in July 1942, was seconded from the R.A.F. to B.O.A.C. as a specialist navigator. In December 1945, he joined B.O.A.C. as Deputy Superintendent of Navigation; in September 1947, he transferred to B.O.A.C. Head Office Operations Branch, and during the past eleven years he had been closely associated with international discussions of I.C.A.O. and I.A.T.A. on various operational subjects such as air traffic control, navigational flying planning, aerodrome requirements, visual and non-visual aids to approach and landing, and operating rules and regulations. He was Chairman of I.A.T.A. Flight Technical Group and was also a regular lecturer to the Royal Aeronautical Society Air Transport Course at Oxford each year.

Captain Prowse was a senior Captain of B.O.A.C. He joined the R.A.F. in 1932 and transferred to civil flying in 1938 with British Airways. When war began he went over to Transport Command and the Return Ferry Service, and had been flying on the Atlantic ever since. He had progressed from Stratocruisers to Britannias, and he would be going shortly to Boeing 707s.

Mr. Coombes was Chief Superintendent of the Aeronautical Research Laboratories in the Department of Supply, Australia. In the past he had been closely associated with Farnborough, from 1924-25, Felixstowe 1925-30, again at Farnborough in charge of the Seaplane Tank in 1930-38, and then in 1938 he had been appointed to establish an aeronautical research laboratory by the Australian Government. Mr. Coombes was particularly welcome at the Royal Aeronautical Society. He had given one of the Commonwealth Lectures; he was a past President of the Australian Division of the Royal Aeronautical Society, and ever since the Commonwealth Advisory Aeronautical Research Council had been in existence, since 1946, he had been leader of the Australian Delegation.

Mr. Calvert was a very well-known worker in the field of safety and regularity in landing. The Calvert Lighting System, he thought, would be known to everybody and a lot of people had a great deal of cause to bless Mr. Calvert's name. His present post was Senior Principal Scientific Officer at the Royal Aircraft Establishment. He had started as an electrical engineer with Metropolitan-Vickers in 1925-28 and then moved to the R.A.E. as Head of the Illuminations Section of the Electrical Engineering Department.

Automatic Air Traffic Control

by

E. W. PIKE, A.F.R.Ae.S.

(*Head of the Air Traffic Control Development Unit, Air Trainers Link Ltd*).

WORLD interest in the development of a satisfactory fully automatic all weather landing system has increased considerably in the past year or so. Statistics on accidents reveal the disquieting fact that a very large percentage occur in the landing phase, either in poor visibility or in conditions where limited or misleading visual clues conspire to affect a pilot's judgment of the required vertical descent path. Factors such as the changed performance characteristics of large turbo-jet aircraft, higher approach and landing speeds and differences in the approach attitude of new aircraft all add to the pilot's difficulties during the landing operation.

It can be unequivocally stated that development of fully automatic landing systems has now reached an advanced stage. In the United States the Bell system (devised for carrier landings) is being applied experimentally to all types of aircraft. It employs a highly accurate auto-follow radar and a special ground computer which observe the aircraft's position and flight path within a few miles of the runway, and calculate continuously any necessary corrections in azimuth and elevations, using the I.L.S. voice channel for transmitting this data to the aircraft, the normal automatic coupling to the auto-pilot being employed for manoeuvring the aircraft in both horizontal and vertical planes. The advantage of being able to handle varied types of aircraft with no special airborne equipment beyond that already required for automatic approach is claimed for this system, which has been demonstrated to international pilots earlier this year.

The Federal Aviation Agency in the U.S. early next year will be starting experiments in the first phase of a more ambitious automatic landing project which will be capable of employing a very large number of approach paths in order to speed movements and provide more flexibility for Air Traffic Control.

In this country the Blind Landing Experimental Unit of the Royal Aircraft Establishment at Bedford has developed and demonstrated most successfully a

blind landing system based on conventional automatic approach equipment and I.C.A.O. standard I.L.S. installations. At a planned stage of the approach, azimuth guidance is taken over from the I.L.S. localiser by guidance from leader cables installed on either side of the runway. A little later, control in the vertical plane is transferred from the I.L.S. glide path to a highly accurate radio altimeter in the aircraft which, in association with a small airborne computer, governs the initiation and control of a pre-set flare manoeuvre. An automatic throttle control device is incorporated to provide the necessary speed stability, drift compensation in a cross-wind landing being achieved by applying corrective action at low altitude proportionate to the angular difference between the known magnetic direction of the runway and the compass heading of the aircraft. All these control sequences are programmed, each system component going into action automatically at a predetermined phase of the manoeuvre.

Two important aspects of automatic flight are being closely investigated. Firstly the safety provisions necessary to offset system failure (for example, auto-pilot runaway) at a late stage of the landing. Multiplexing auto-pilot channels as a means of overcoming this danger is being studied. Secondly the requirements for an independent monitoring system have to be determined as pilots are very naturally opposed to placing complete reliance on black boxes unless their performance can be closely watched by some such means as a televised picture of the runway or a synthetic visual display in the cockpit. This is a somewhat contentious subject which I would rather Captain Prowse covered, because I feel pilots ultimately will decide just what they must have as protection against system malfunctioning. Of course, the incorporation of adequate safety features in an automatic landing system in respect of both the airborne and ground components is initially the responsibility of certificating authorities such as the Air Registration Board and the Ministry of Transport and Civil Aviation.

The strength of the requirement for all-weather landing may best be gauged by reference to authoritative sources. The International Air Transport Association, following an exhaustive review of the state of the art a year ago, agreed (and I quote)

> "Scheduled all weather landing, a definite airline objective, is now regarded as inevitable and will be capable of achievement at some future date, largely consequent upon the research efforts devoted to the solution of remaining problems."

A recent paper expressing the philosophy of the Federal Aviation Agency in the United States on approach and landing system developments contains the following paragraph:

> "Never has the requirement for an instrument landing capability been greater than it is today. It is urgently required by the operational echelons of our military establishment whose reaction must be instantaneous regardless of weather. It is needed by the air transport industry for safety and economy of operation. It is demanded by the passenger or business pilot required to be at the right place at the right time, and it is an absolute must to the air traffic control system if it is to be able to provide for the safe and expeditious flow of the volumes of air traffic presently foreseen."

It has been calculated recently that the provision of safe all-weather landing capability in the U.S. would be worth 25 million dollars annually to the civil aviation industry of that country.

Take-off problems are increasing in importance mainly because of a marked rise in aircraft weight. It is becoming more difficult for both technical and economic reasons to add appreciably to the length and strength of existing runways, which, combined with the fact that the newer generation of large turbo-jet aircraft must be flown very strictly in accordance with the prescribed numbers, means that pilots have to become used to seeing the end of the runway much nearer before raising the nosewheel, or to use the latest U.S. term "commencing rotation."

There is still considerable doubt as to whether a real requirement for automatic take-off exists in view of the fact that, provided that the pilot can be given assistance in keeping the aircraft coincident with the centreline of the runway during the take-off roll in bad visibility and be told how much runway is remaining ahead of him, he can probably carry out the other control functions quite satisfactorily by manual means. However, because of the necessity for a rapid and accurate decision as to whether or not to abandon a take-off due to inadequate engine thrust or because of ground influences such as slush or water on the runway, there has been a strong demand for an improved means of monitoring take-off performance. The existing method of complying with predetermined V_1 and V_2 speeds appears in some respects rather crude, and many ingenious and promising alternative devices have been suggested. Important points seem to be deciding the best method of presenting the right information to the pilot based on the integration of both the distance travelled and acceleration experienced during take-off.

In both the take-off and the landing cases there is undoubtedly a real safety factor in providing additional concrete beyond that required to meet performance regulations. Also, doing everything possible to provide on the approaches to runways level compacted ground free of all obstructions, makes a major contribution to safety besides improving an operator's economy where he is allowed to calculate his take-off weight on the basis of an unbalanced field length. In such cases the aircraft is permitted to reach its screen height at a point beyond the end of the runway, *i.e.* in the clearway.

Efficient reliable braking capacity naturally plays a major part in both landing and during an aborted take-off. Pilots have commented very favourably on the latest types of automatic braking. I have a personal conviction that airport authorities will have to give serious thought to the desirability of installing arresting devices at the end of runways used by large jet aircraft for emergency purposes. The water squeezer type developed in the U.S. seems highly promising and works on principles roughly similar to those used in landing on aircraft carriers.

The Pilot's Problems

by

CAPTAIN B. O. PROWSE
(Senior Captain, British Overseas Airways Corporation)

WHEN considering the problems of take-off and landing from the pilot's point of view, the most important fact to remember is that he is a human being. This drawback immediately limits his capabilities in the operation of an aeroplane because the control of a pilot's actions is through the computer we call the brain. This computer, although extremely efficient in almost all functions, has nevertheless serious limitations when it comes, first, to speed of computation, and secondly, the number of functions it can compute at one time.

Until now the speed of operation of aircraft has been compatible with the speed of computation of the human brain that is governing the pilot's reactions. Also the size and complexity of the aircraft and the operation have been compatible with the number of functions the brain can compute at one time.

Now, however, with aircraft such as, for example, the Boeing 707, we have arrived at the stage where this compatibility just about ends. The human pilot is approaching a stage beyond his design capabilities. Emphasis is required on improved instrument, system and cockpit design and simplification of ATC procedures aided by automatic computing equipment.

Being human, the pilot's physical abilities are considerably affected by his emotional state. This is one of the inefficient aspects of the human brain when used as a computer for the operation of an aeroplane. The computations are affected by unwanted emotional inputs which damage the accuracy of the answers coming out. Computers should be affected only by inputs essential to the problem. Most airline managements are aware that deaths have occurred and aircraft been lost while being operated by pilots who have continuously been checked as absolutely satisfactory operationally. Subsequent investigations have frequently shown that unusual emotional states have almost certainly existed, caused by incidents in their private lives. The very large number of near misses attributable to this cause will never be known. The less emotional a pilot is, the stabler and safer is his operation, and the most difficult part of operation is the approach and landing. I am laying this very heavy emphasis on the human failings of the pilot with his place *in* the operational loop of modern aircraft, because it must be with this weakness in mind that aircraft manufacturers design their equipment. In the case of all contemporary jet aircraft and probably all subsonic aircraft the pilot will be in the loop, except, possibly, in the landing operation. This depends on the speed of progress towards a satisfactory auto-landing system. It must be very clear to airline operators and manufacturers that, for safe all-weather operations, in supersonic aircraft, an attempt must be made to design the human pilot out of the operational loop, although, of course, not necessarily out of the cockpit.

Landing

Now I come to the pilot's more specific problems in the operations of take-off and landing. First, consider a landing on a normal clear day. The pilot is using what we now know to be a pretty inefficient brain computer to make his judgments of height and distance. His eyes are the chief source of input information. They are checking heights and distances from outside the cockpit, and speed, height, rate of change of height and angle of bank from instruments inside the cockpit. These inputs result in physical reactions that execute a circuit and landing. Being this inefficient human computer, however, these inputs are being affected by such variants as the total flying experience of the pilot, the number of landings he has done recently, the runway conditions in relation to the friction coefficient, the cross-wind component, the length of the runway and many others including the emotional ones mentioned before. Depending on the number and strength of these variants inputs, and the extent to which the general operational efficiency of his brain is being affected by fatigue, he will execute the circuit and landing well—or badly.

The state of light is very important. A landing on a clear day is the easiest because the large quantity of useful input information is simple to compute. Next easiest is a landing on a clear night with good approach and landing lighting. After this a daylight landing in visibility of three miles or less, requiring additional input information usually in the form of an ILS localiser and glide path, or a visual glide path indicator. Finally the most difficult landings are in really low visibilities—around 400 yards—when the input information is derived entirely from inside the cockpit until the aircraft is down to a height of approximately 200 feet above the ground. The input information is changing rapidly, is complicated to compute and must be computed very fast. It is when the pilot's brain has reached this point, on the verge of being unable to compute, that the pilot is said to be fully "loaded."

This loading is increased by an emotional factor called anxiety, which is a definite physical feeling. On an approach to land in low weather minima this feeling builds up to a peak at about 250 feet above the ground, or 15 seconds before the threshold. The degree by which this factor increases the loading is directly proportioned to the amount of recent flying of this type that the pilot has done. In 27 years flying, 21 years of airline operation, I think that in only about three cases

of this kind of landing have I personally *not* felt this anxiety peak.

Automatic approach down to, say, 200 feet, in 400 yards visibility, with the pilot monitoring the operation but doing the landing himself, enormously increases safety. The poor old brain computer only has to monitor the approach—an operation well within its ability. Pilot loading is very low, and the anxiety factor is greatly reduced. Progress from here to fully automatic approach and landing, with equipment which is approved and accepted, and the degree of safety is again increased. The job of computation is now at its simplest and extraneous factors are negligible.

The pilot has to contend with a brain computer of limited capacity, with his own natural emotionalism and the limited amount of flying practice the airline is able to let him have. The contemporary batch of large jets should not be operated with the same old instruments that have been used for years on such aircraft as the DC-6, the DC-7 and the Britannia. Yet attempts are being made to do this. Take the gyro horizon for instance. This instrument is seriously affected by acceleration, to such an extent that it cannot be safely used on take-off in the latest large jets. At the same time acceleration causes swirl effect on the pilot's brain, resulting in inability by him to interpret the gyro horizon indications correctly. This is just one example among many.

Then we have to contend with another influence which has unavoidably entered the field. This is the distrust with which practically every pilot who has ever used electronic black boxes views these objects. They have malfunctioned very many times over the years, so that pilot faith in them has become extremely low. To try to persuade pilots to entrust themselves and their passengers to a landing controlled entirely by black boxes, *i.e.* fully automatic landing, is going to be no easy job. The number of pilots who can be persuaded to use even the automatic approach functions that can be switched into the auto-pilot is small enough today. I firmly believe that some form of separate source monitoring of fully automatic landings will be most necessary during its introductory years at least. The type of television display monitoring being developed at B.L.E.U. would seem very suitable. To fit multiplex auto channel equipment and try to persuade pilots how unlikely it is to let them down by quoting a probable failure rate of one in so many million landings will be a waste of time and money.

Take-off

The take-off operation is much simpler and less dangerous than the landing, and has resulted in far fewer accidents. The effectiveness of propeller reversing has contributed largely to this. The comparative ineffectiveness of reverse thrust makes the take-off of a large jet much more critical. Mr. Pike mentioned what he described as the rather crude method of complying with predetermined V_1 and V_2 speeds. These speeds must be related to time or distance in order to be of use in *monitoring* a take-off. I personally consider that a take-off monitor is essential in these large aircraft; one computing distance from acceleration dynamic pressure and distance would probably be the best system, though rather complicated technically. I have no practical experience in the use of take-off monitors myself.

Automatic take-off is a subject about which I know very little. It may be necessary in the supersonic era in order to achieve 100 per cent all-weather operation.

There is a great deal more that could be said on the take-off and landing problem, such as for instance, to discuss Fido, but time does not permit. If I have put over to you the fact that the pilot requires every possible assistance in the simplest and most reliable form, then I have achieved my objective.

The Human Engineering Approach

by

L. P. COOMBES, D.F.C., B.Sc., F.R.Ae.S.
(*Chief Superintendent, Aeronautical Research Laboratories, Melbourne*)

I CLAIM to have no expert knowledge on landing aids, but the Aeronautical Research Laboratories in Australia have done some work in this field. We were invited, or encouraged, to take up this branch of work by a Meeting of the Commonwealth Advisory Aeronautical Research Council in Australia in 1955, when the difficulties of the landing phase and the need for some form of aid for the pilot were emphasised.

I need say nothing about the difficulties of the pilot: they have already been amply emphasised. An early example of operational research in this field was an investigation made by Professor Collar in 1941 on the problem of the dark night take-off, when the pilot tends to mistake forward acceleration for a climb in the absence of sufficient external visual cues. Although this was written up at the time, four DC-3 aircraft were lost in Australia during the years 1946 to 1954 in these very circumstances and a check revealed that the possibility of this illusion was not generally known in aviation circles. Certain international accidents also seem to have been the result of the same illusion.

Another more recent example of such research was the distribution of a questionnaire to civil and military pilots in Australia to find out how pilots make a judgment necessary for the approach and whether they consciously use specific visual cues. About 300 replies

were received and the analysis yielded much useful background information, from which I will mention a few points.

When traffic is favourable, both airline pilots and pilots of military piston-engined aircraft prefer to make straight-in approaches by day under good visibility conditions for reasons of expedition and economy. Conditions which allow no natural horizon and those in which there is an absence of foreground texture both cause a large reduction in the preference for straight-in approaches. This emphasises the assistance which the circuit gives to the pilot by standardising the position of the aircraft at the start of the approach; in effect it eliminates the need to make the judgment of one variable from his task. Military jet pilots almost always prefer a circuit, mainly to dissipate excess speed, but also partly to assist their judgment.

Most pilots consciously use a point of aim on final approach and most civil and military instructors teach the use of an aiming point. The location of the aiming point for those pilots who make use of one is close to the runway threshold.

The distribution of intended touch-down points given by airline and military pilots cannot be reconciled with touch-down points observed at an airport. It is possible that the pilots' answers reflect a desire rather than an expectation; on the average they land farther along the runway than they intend to. Both airline and military pilots rate the risk of under-shooting or over-shooting as equally likely, thus over-estimating the risk of overshoots and under-estimating that of undershoots.

More than one third of the pilots reported an uncomfortable incident on final approach in the preceding twelve months. More than half of these were related to deviations from the desired glidepath and about one-sixth to deviations in alignment. There was a marked preponderance of incidents associated with the circumstances of a moonless dark night and unlit foreground. There was a rather less pronounced association of under-shooting incidents with straight-in visual approaches.

The main object of the questionnaire was to discover what cues were used by airline and military pilots and were taught by instructors to assist in the recognition of under-shooting or over-shooting on final approach. Rather less than half of the pilots and instructors were able to give specific information on this point.

Information of this type gives a factual background on which to base a research programme by showing up the circumstances in which visual aids are required and helping to determine what form they should take. In Australian operations, where many airfields are away from built-up areas and few have approach lighting, the need for visual guidance seems greatest in glide path and roll during approaches on dark nights, particularly in the absence of a visible horizon and natural foreground lighting. Similar conclusions will not necessarily be reached in other countries which differ in respect to population density and weather conditions and this no doubt explains the different approaches to the problem being made in the various countries.

As is probably well known, ground based visual aids for glidepath guidance have been developed both in this country and in Australia and they differ in a number of respects, as might be expected from their different backgrounds of development. A number of each are currently being installed in the United Kingdom, Australia and elsewhere, and their performance in operational use will be closely studied. Our system in Australia is a fairly simple one of two sets of lights, one on poles, one on the actual ground, giving the glide path and also it is used as roll guidance; I think it will be familiar to a number of people.

In addition airborne aids for approach guidance are under development in both countries. The objective is to eliminate the need for a pilot to change from one guidance system to another at a low altitude. In Australia the problem is being tackled by projecting something similar to an Integrated Flight System director instrument on to a reflector plate which can be folded down in front of the pilot's eyes; air speed information will also be included. Thus the pilot can see, can focus at infinity, the display, so that he does not have to refer to instruments in the cockpit itself.

Yet another problem, basically a visual one, is the difficulty of judging the precise height above the runway for the round-out and hold-off prior to landing. This judgment is always important from considerations of runway length, but, when landing in a cross wind, it becomes more critical with the need to kick off drift at the right instant. In daytime the pilot judges his round-out and drift correction from the texture of the runway and surrounds, and at night from patterns of lights along or on the runway, which are intended to replace the ground texture he uses in daytime. These are always difficult judgments and are subject to considerable variance.

It is interesting to note that, when there is no human in the system, means are found for giving the round-out information more precisely than the average pilot can judge it. At the Blind Landing Experimental Unit a radio-altimeter is used, while in Australia on the Jindivik, we simply use a piece of wire operating a microswitch.

Possibly there is a case for considering devices of this type to assist in the manual landing of aircraft, particularly at high speeds. After all, what the pilot really wants to know is when he has reached some particular height above the runway surface, or possibly two particular heights. His judgment of when the ground texture or the light pattern appears in a certain perspective is only a means to an end. Therefore, rather than assisting this judgment by improving the available visual cues with additional runway markings and lights, it could possibly be better to supplement it and provide the information he wants more directly.

This is merely a suggestion at this stage, but with the fast approach speeds and narrow undercarriage tracks of some jet aircraft, the problem will be accentuated and we may certainly need to consider these aids.

Safety and Regularity in Landing

by

E. S. CALVERT
(Royal Aircraft Establishment)

(Spoken Introduction)

THE paper I have presented to you here is a brief account of the work we have been doing in the past six years at Farnborough and B.L.E.U. In studying visual judgments during the past few years, we have been driven to one conclusion which is pretty well the same as that which Capt. Prowse put before you, namely, that we are reaching the limit of what the human being can do. Every visual task has a certain failure rate, and I think this rate depends on the value of V/ak, where V is the approach speed, a is the acceleration which the pilot is able and willing to apply during a corrective manoeuvre, and k is an index representing the goodness of the visual stimuli. The tendency is for V/a to increase as aircraft get larger and heavier, but we have hitherto managed to counteract this by improving the visual aids, *i.e.* by increasing k. There is, however, a limit to this improvement, and when this is reached, as I think it will be when runways are equipped with the visual aids which have now been developed, I think that a point may be reached where the design will be limited by the operational environment, and the necessity of maintaining an acceptable level of safety at an economic cost. In other words, we will have to consider the aircraft as merely one item in the whole system of transport. This means that we must pay far more attention to Operational Research, and not let ourselves be fascinated by techniques.

We have come to the conclusion that the phrase "visual guidance," which appears in many of the regulations, is very nearly meaningless, because there are two visual guidances, one for the horizontal plane, and one for the vertical. Visual guidance in the horizontal plane presents no difficulty to anybody if the runway is equipped with a centre-line and cross-bars system, provided the cross-bars are wide enough. As regards the vertical plane, I do not believe any ground pattern will produce the guidance which will be necessary in the future; it will have to be supplemented by a visual glide path indicator for the very large aircraft. That is why we at the R.A.E. have devoted so much time to trying to deal with this problem of guidance in the vertical plane. There are other ways of dealing with the problem, such as the head-up director which Mr. Coombes mentioned, and which is being tried in various forms.

In my paper I have mentioned a number of palliatives which might be introduced almost immediately. One of them is a different cockpit procedure whereby one pilot does the instrument approach and another pilot looks out for lights and then takes over. This has been much discussed by I.A.T.A. Another suggestion is that in the case of G.C.A. approaches it is not necessary for the controller to give azimuth information after the aircraft has descended below critical height. Instead he should concentrate on the vertical information, which should be given in a steady rhythm. Another suggestion is that safety could be increased using simulators to show the bad weather situation. I say "the bad weather situation" because I hope the good weather situation will be solved by some form of vertical glide path indicator. The fourth and last thing I should like to suggest is that it ought to be possible to get better information about the weather conditions below, say, 300 ft.

1. Introduction

THIS paper has been prepared in the hope that it will do something to reduce the number of accidents due to visual misjudgments at landing during the next few years when the new jet transports will be coming into widespread operation. It attempts to do this by drawing attention, first, to the limitations of visual guidance in the vertical plane, secondly, to any special conditions likely to lead to a high accident rate, and thirdly, to the procedural implications of these limitations. The information given has been obtained from perspective analysis and simulator tests, from accident reports, and from a statistical examination of a large number of visual landings made in the U.S. and the U K. during the past ten years.

2. The Present Levels of Regularity and Safety in Civil Operations

The use of the crossbar principle in approach lighting systems greatly improved visual guidance in the horizontal plane, and this has enabled many types of aircraft to operate at runway visual ranges as low as 500 yards. It also reduced the proportion of go-arounds in visual ranges of the order of half a mile from more than thirty per cent to less than two per cent, and this, together with the reduced limits, has enabled a high level of regularity to be maintained. The use of multiple crossbars also improved the guidance in the vertical plane, and on a modern runway equipped with a precision approach aid and a five bar crossbar system, the accident rate in civil operations due to visual

misjudgments at landing is probably less than 2 in 1,000,000. Most pilots would, however, agree that, even with the full treatment, the visual guidance in the vertical plane is marginal for present-day civil operations, and that this level of safety has only been maintained with difficulty. At runways with an abbreviated or no approach lighting system, the accident rate due to visual misjudgments is higher, and where conditions are specially difficult, may exceed 1 in 10,000. As in all tasks which are near the limit of what a human being can do safely as a routine job, a small increase in the difficulty of the pilot's task might increase the accident rate by an amount out of all proportion to the increase in difficulty. For instance, in the U.S.A.F. the accident rate in 1953–54 due to visual misjudgments at landing was 7½ times greater for jet aircraft than for propeller-driven aircraft. While military operations are very different from civil, this illustrates the desirability of doing everything possible to reduce the load on the civil pilot during the years immediately ahead. The new integrated flight systems will contribute to this, and so will two recent developments, the Visual Glide Path Indicator, and the so-called Head-Up Flight Director. The Visual Glide Path Indicator is just going into production, and could be installed at all important runways during the next two or three years. The Head-Up Director is beginning to be developed, and already shows considerable promise. It is probable, therefore, that the present level of safety in visual landings can be improved in the future, even with jet aircraft, if the measures necessary to do so are generally understood and implemented internationally. The main objects of this paper are, firstly, to stimulate interest and discussion, and secondly, to make practical suggestions as to what might be done to keep down the accident rate in the interval before these two new aids come into operation.

3. The Elements of Guidance, and how they are Obtained Visually from a Ground Pattern

The path which the pilot desires to follow during an approach may be regarded as the intersection of two reference planes, the glide path, and the vertical plane through the centre-line of the runway. In order that the approach may be stable and accurate, the pilot needs to know continually the values of six variables:

(*a*) the displacement relative to each reference plane,

(*b*) the track heading, or rate of closure, relative to each reference plane,

(*c*) the rate of change of the track heading (rate of turn) relative to each reference plane.

In correcting an error in either plane, the pilot's task is continuously to match heading against displacement, so that at the moment when the displacement eventually becomes zero, the relative track heading and rate of turn have also become zero. At any given moment the two displacements, (*a*), are indicated by the *shape* of the perspective image of the ground pattern. Displacement information is, therefore, practically instantaneous. The two track headings, (*b*), are indicated by *changes in the shape* of the image. To obtain this information, the pilot must observe the pattern for a period of time, the length of which increases with height, *i.e.* rate of closure information is *not* instantaneous. Track heading is also indicated roughly by the apparent *position* of the more distant parts of the pattern relative to the windscreen framework. The two rates of change, (*c*), of track heading (rates of turn) are indicated by the horizontal and vertical *velocities* of the whole visual field relative to this framework; in the horizontal plane it is also indicated by the angle of bank. In addition the pilot obtains information with respect to the rate of change of heading in the vertical plane from manual feel, and from his knowledge of the stability characteristics of the aircraft. These last two sources of information are of very great importance for safety.

The visual indications associated with the two reference planes differ in two respects, and it is essential for safety to realise clearly what these differences are, and that they are inherent in the nature of the visual guidance which can be derived from ground patterns. The first difference is that zero displacement with respect to the vertical reference plane is indicated by the perspective image of the centre-line of the runway (or approach pattern) being perpendicular to the horizon, to the crossbars, or to both, depending on the visibility and ground pattern (*see* Fig. 1). This means that, with a symmetrical ground pattern, zero displacement is indicated by the symmetry of the image about its centre-line. Since small departures from symmetry are immediately and easily recognised without special training, it follows that even small lateral errors can be instantly recognised as soon as one crossbar comes into view. Reductions in visual range, therefore, have little effect on regularity down to the range at which one crossbar is visible at critical height. In contrast to this, displacement above or below the glide path merely results in vertical extension or compression of the image, as shown on Figs. 2 and 3, and zero displacement is indicated, not by a unique symmetry in the image, but by the identity between the actual image, and an ideal image which the pilot carries in his mind. Because the differences between the ideal image representing zero vertical displacement, and an image representing even a large vertical displacement, are small, the pilot must, from time to time, concentrate all his attention on making this mental comparison. Undue fatigue, or an increase in the difficulty of his task, such as that caused by turbulence, or the failure of an engine, will, therefore, impair the accuracy of the comparison, and greatly increase the probability of a serious misjudgment. What is worse, however, is that progressive reductions in the visual range remove more and more of the upper part of the image, and progressively mask the extension and compression due to displacements above and below the glide path. Simulator tests on the five bar crossbar pattern indicate that, in marginal visibilities the average pilot recognises a dangerous situation at a height of about 100 feet, but whatever this

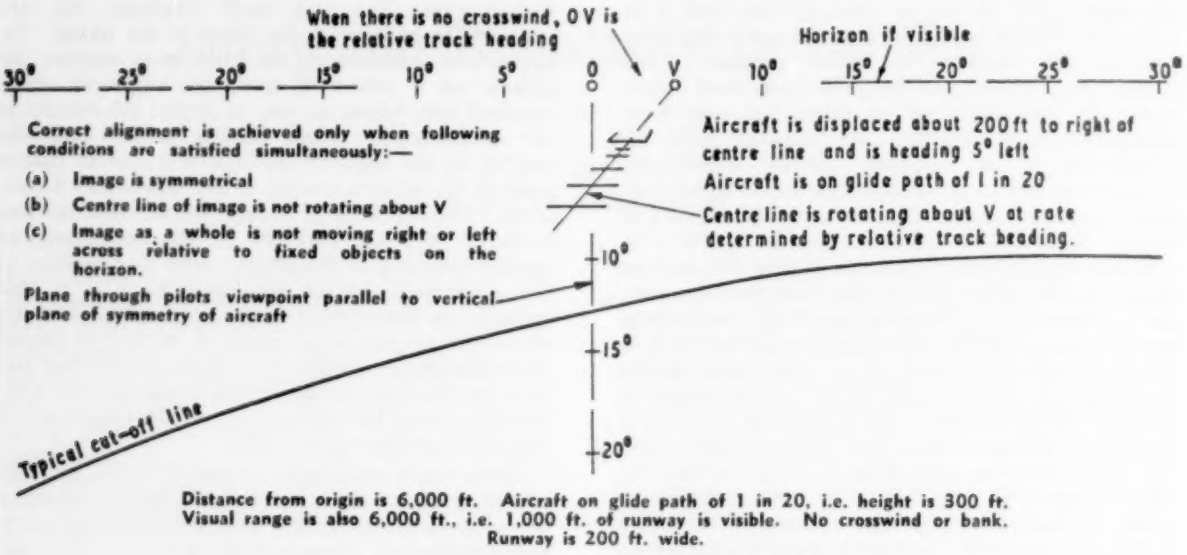

When there is no crosswind, O V is the relative track heading
Horizon if visible
30° 25° 20° 15° 10° 5° 0 V 10° 15° 20° 25° 30°
Correct alignment is achieved only when following conditions are satisfied simultaneously:—
(a) Image is symmetrical
(b) Centre line of image is not rotating about V
(c) Image as a whole is not moving right or left across relative to fixed objects on the horizon.
Plane through pilots viewpoint parallel to vertical plane of symmetry of aircraft
Aircraft is displaced about 200 ft to right of centre line and is heading 5° left
Aircraft is on glide path of 1 in 20
Centre line is rotating about V at rate determined by relative track heading.
10°
15°
20°
Typical cut-off line
Distance from origin is 6,000 ft. Aircraft on glide path of 1 in 20, i.e. height is 300 ft.
Visual range is also 6,000 ft., i.e. 1,000 ft. of runway is visible. No crosswind or bank.
Runway is 200 ft. wide.

FIGURE 1. Lateral error in process of being closed prior to final turn.

height is it is sufficient, in present day operations, to prevent the accident rate rising above the figure given in Section 2, *i.e.* 2 in 1,000,000. Since the accident rate for runways with only a simple line of lead-in lights may be anything up to 100 times higher, it would seem that the height at which a dangerous situation is realised must, with this pattern, be even lower than 100 feet. (A classical example of this is the accident which occurred at Belfast in January 1953.) In such cases it is clear that the response characteristics of the aircraft in the approach configuration are of vital importance.

The second difference between the visual indications associated with the two reference planes is that an error in heading in the horizontal plane is shown by the continuous rotation of the longitudinal elements of the image in an anti-clockwise direction, if the error is to the left, and in a clockwise direction, if the error is to the right. In the vertical plane there is no comparable simple connection between the heading in the vertical plane (instantaneous angle of descent) and the movement of any of the elements of the perspective image. The result of these two differences may be summed up by saying that a pilot can detect a small lateral error, and see in a few seconds whether it is increasing or decreasing, whereas he can only detect a height error if it is large, and will not know for many seconds whether it is increasing or decreasing. As an example, in some tests made on large military jets, it was found that the angle of descent in purely visual approaches varied from 1·4° to 5·4°, and that the touchdown points were spread over a distance of 2,000 ft. The lateral errors, on the other hand, were very small.

Because the vertical situation is so difficult to assess accurately, the pilot will try to check his judgment of it in every way he can. One way of checking this at low heights is to estimate the height from a knowledge of the appearance of textural features, such as trees, houses, roads and to a lesser extent, the size and spacing of the approach lights, and then, by means of past experience, set this height against estimated range from touchdown. When the approach is over water or featureless terrain, such as desert, the pilot is unable to obtain this additional information and the accident rate increases. It increases still further if the terrain has a pronounced slope, or if there is a range of mountains, or some other peculiarity, which gives a wrong impression of the position of the real horizon. At night the textural indications are fewer than in the daytime and the horizon is usually less definite, with the result that the accident rate at night due to visual misjudgments is about twice as high as by day. Since, however, there are about five times as many landings by day, the total accidents by day are more than double the total accidents at night. This is why the new V.G.P.I. has been designed to be effective by day as well as at night. About 75 per cent of all these accidents occur in visibilities above 2 miles, from which it follows that the V.G.P.I., since it provides useful guidance right down to flare-out, should effect a very substantial reduction in the overall rate.

It has been found that for transport aircraft the average time taken to correct a lateral error during a visual landing is nearly independent of speed, and for an error of 100 feet, is about 12 seconds. During this correction the visual guidance in the vertical plane is impaired by the rolling of the aircraft to such an extent that, with a poor ground pattern, it may be reduced almost to zero if the bank angle is large. When a lateral error has to be corrected visually after an instrument approach in bad visibility, the pilot may steepen the angle of descent unconsciously because of the absence of guidance, or he may do so consciously because he knows that the aircraft is above glide path.

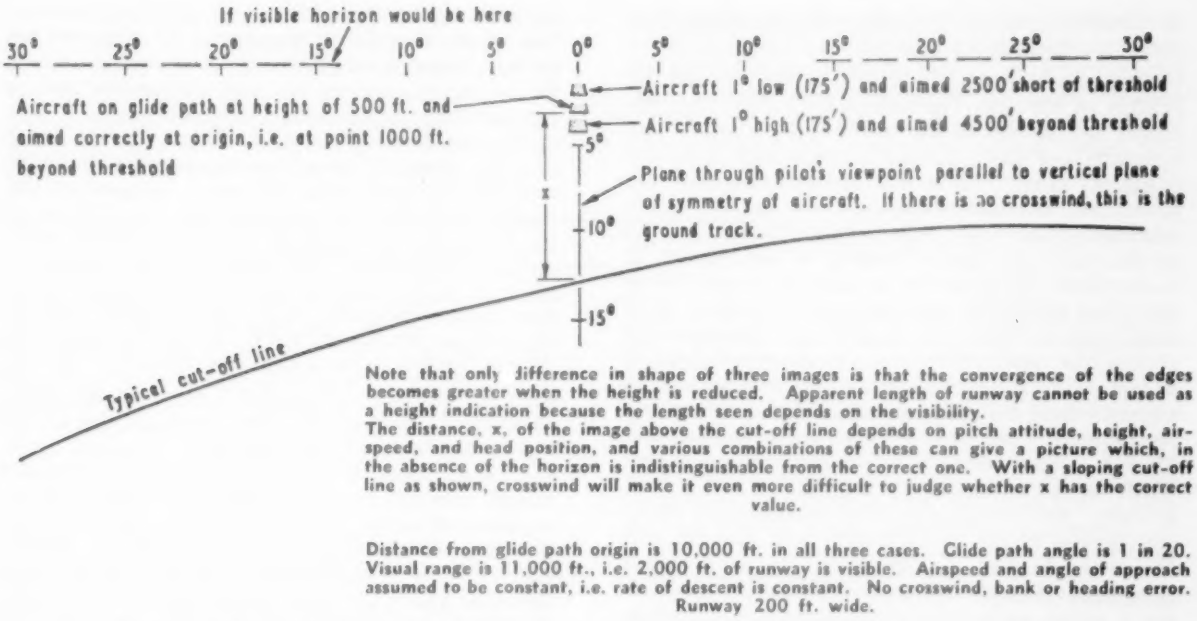

If visible horizon would be here
30° 25° 20° 15° 10° 5° 0° 5° 10° 15° 20° 25° 30°
Aircraft on glide path at height of 500 ft. and aimed correctly at origin, i.e. at point 1000 ft. beyond threshold
Aircraft 1° low (175′) and aimed 2500′ short of threshold
Aircraft 1° high (175′) and aimed 4500′ beyond threshold
x
5°
10°
15°
Plane through pilot's viewpoint parallel to vertical plane of symmetry of aircraft. If there is no crosswind, this is the ground track.
Typical cut-off line
Note that only difference in shape of three images is that the convergence of the edges becomes greater when the height is reduced. Apparent length of runway cannot be used as a height indication because the length seen depends on the visibility.
The distance, x, of the image above the cut-off line depends on pitch attitude, height, airspeed, and head position, and various combinations of these can give a picture which, in the absence of the horizon is indistinguishable from the correct one. With a sloping cut-off line as shown, crosswind will make it even more difficult to judge whether x has the correct value.
Distance from glide path origin is 10,000 ft. in all three cases. Glide path angle is 1 in 20. Visual range is 11,000 ft., i.e. 2,000 ft. of runway is visible. Airspeed and angle of approach assumed to be constant, i.e. rate of descent is constant. No crosswind, bank or heading error. Runway 200 ft. wide.

FIGURE 2. Height and aiming errors as they appear when only the runway is visible and there is no horizon.

or that the runway is critical for length. Because the height at which a dangerous situation is recognised is so low, and because the degree of steepening cannot be assessed visually until a few seconds after removing bank, this steepening involves an element of danger which is greater the worse the visibility. Furthermore, any increase in the instrument approach speed, by increasing the height required to check the rate of descent, will increase this danger. The contribution which the integrated flight system makes is mainly to safety, and derives largely from the fact that errors are smaller, and that there are fewer occasions on which corrections have to be made. The danger would be completely removed by a reliable type of head-up director, because, in this case, the command information would be available to the pilot, even when he was looking out, down to the height at which the instrumental system became unusable. With improved glide path aerials and a good site, this might be as low as 60 feet.

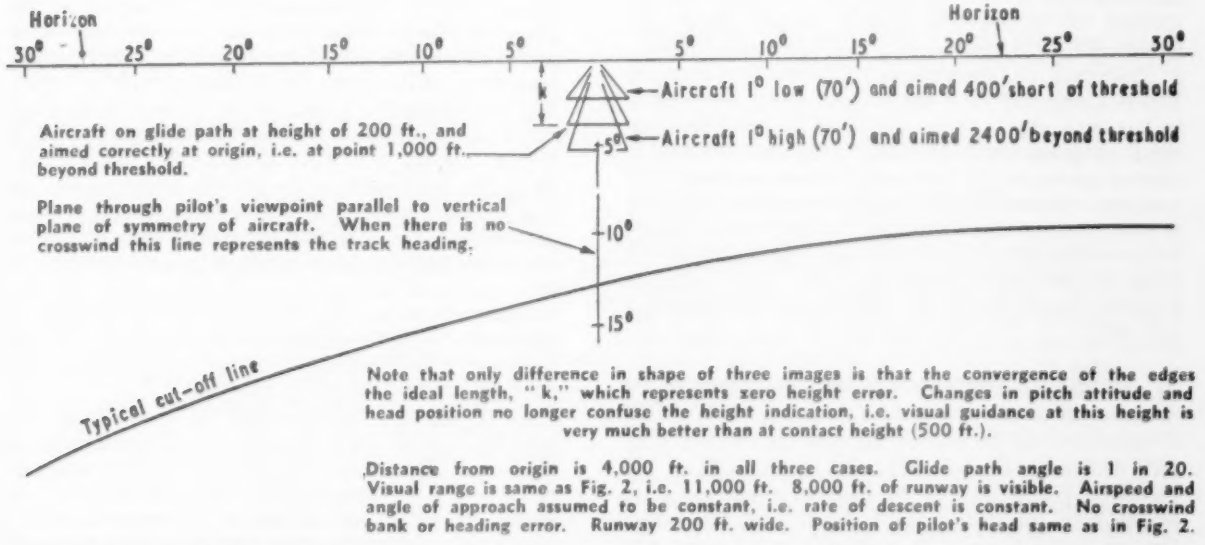

Horizon
Horizon
30° 25° 20° 15° 10° 5° 5° 10° 15° 20° 25° 30°
k
Aircraft 1° low (70′) and aimed 400′ short of threshold
Aircraft on glide path at height of 200 ft., and aimed correctly at origin, i.e. at point 1,000 ft. beyond threshold.
5°
Aircraft 1° high (70′) and aimed 2400′ beyond threshold
Plane through pilot's viewpoint parallel to vertical plane of symmetry of aircraft. When there is no crosswind this line represents the track heading.
10°
15°
Typical cut-off line
Note that only difference in shape of three images is that the convergence of the edges the ideal length, "k," which represents zero height error. Changes in pitch attitude and head position no longer confuse the height indication, i.e. visual guidance at this height is very much better than at contact height (500 ft.).
Distance from origin is 4,000 ft. in all three cases. Glide path angle is 1 in 20. Visual range is same as Fig. 2, i.e. 11,000 ft. 8,000 ft. of runway is visible. Airspeed and angle of approach assumed to be constant, i.e. rate of descent is constant. No crosswind bank or heading error. Runway 200 ft. wide. Position of pilot's head same as in Fig. 2.

FIGURE 3. Height and aiming errors as they appear when nearly all runway is visible and there is a horizon.

4. Implications for Safety Regulations and Operating Limits

The present definition of Critical Height, and the concept of Obstacle Clearance Limit, imply that the danger lies mainly in the instrument portion of the approach, and that "reference to the ground" somehow produces "safety." It is now realised that, with the advent of rate-aided couplers, this is no longer necessarily true. Clear definitions and concepts, based on the real facts, have a bearing on the amount of blame which may be laid at the door of the pilot in the case of an accident in which no cause other than "pilot error" can be found. It is therefore suggested that phrases like "adequate reference to the ground" should be replaced by a clear statement of the minimum visual segment which the pilot must see before he continues the approach. Secondly, it should not be implied that there is a sharp division between safety and danger which can be recognised by the pilot in a matter of seconds. Accidents due to visual misjudgments represent failures of the visual control loop, *i.e.* the loop comprising the pilot, the aircraft and the visual ground aids, and safety in this connection is not absolute, but is simply what the statistics show it to be. Data should therefore be collected continuously to enable the levels of safety and regularity to be determined year by year for the various visual control loops. If this were done by each country with a large volume of air traffic, and the results exchanged through ICAO, the international standardisation so necessary for safety would be greatly accelerated.

Whatever coupler is used (short of automatic landing) the Critical Height cannot be lower than the height at which go-arounds can be made on instruments with a level of safety acceptable to the operator. Since visual guidance in the vertical plane becomes worse as the height increases, as shown in Figs. 2 and 3, it is suggested that, when a *reliable* rate-aided coupler is used, the level of safety is not raised, and may even be lowered, by raising the Critical Height above the minimum fixed by the necessity for being able to make a go-around on instruments. Raising the Runway Visual Range *will* raise the level of safety, but with a bad pattern, the increase has to be large to produce much improvement. The only way of effecting a substantial rise in the levels of regularity and safety at a difficult runway in the immediate future is therefore to improve the visual guidance in the vertical plane, *i.e.* by installing an effective type of V.G.P.I. for use in visual ranges above about one mile, and a multiple cross-bar pattern for use in visual ranges less than about one mile.

5. Practical Suggestions for the Immediate Future

Because rate of closure information, by the very fact that it is a rate, cannot be instantaneous, the procedure (often used in the past) in which one pilot makes both the instrument approach and the visual landing, leaves a gap in the guidance for a few seconds after leaving instruments. Another, and very strong, argument against this procedure is that, if the combination of errors and drift happens to be such that the pattern appears at an angle to the dead ahead direction, the downward views of the pilot and co-pilot will be very different. For instance, if the drift angle is 20°, the downward view of one pilot will be about 10° and of the other about 20°, for a typical transport aircraft. If, therefore, the pilot looks up when the co-pilot calls "lights," it may be 5 or 6 seconds before he has enough visual guidance to control the aircraft accurately. Since manual approaches with flight director require a relatively small degree of skill, it should be possible in the future to arrange that the pilot who is to make the visual landing looks out for the lights, and takes over only when he is satisfied that he already has a grip on the visual situation. If the errors are small, the height at which he elects to take over may be as low as 150 feet, *i.e.* well below critical height.

It is suggested that in a G.C.A. approach the pilot should give the controller his critical height at the beginning of the talk-down. When the aircraft reaches the range corresponding to this height on the nominal glide-path, the controller should announce the fact, and thereafter give glide-path information only. To continue to give range and azimuth information beyond this point on the approach is simply to add "noise" to the control system, because if the pilot has made contact with the visual system (and he cannot legally continue the descent if he has not) he already has better range and azimuth information than the controller can give him. Beyond this critical point on the approach, glidepath information should be given in a steady rhythm at intervals of about one second, so that the pilot can extract a rate. The one thing which must always be avoided is to give the pilot glidepath information which leads him to increase his rate of descent just as he goes visual, and then stop the flow of information before he has re-established a safe and stable rate of descent. There is good reason for thinking that a stoppage of this kind, or unduly long intervals in the glidepath checks when near the ground, may have contributed to many undershoot accidents. With present procedures, if the pilot, due to some disturbing factor, fails to assimilate a height check, he may be as much as 14 seconds without any height information. This is far too long for high-speed aircraft when below break-off height, particularly if the aircraft is at a speed such that the pilot has to use the throttle to control the rate of descent. The proposed procedure has the added advantage that the actual break-off point is not affected by errors in the altimeter. (It is understood that, due to hysteresis in the capsule, these may be as large as 200 feet.) It also eliminates the possibility of the controller making an error through changing back and forwards from one scope to the other.

It is suggested that, pending the development of a head-up type of flight director, the flying training of civil pilots should be supplemented by demonstrations given partly by means of an instructional film, and partly by means of a simple bad-weather landing simulator. The main object of these demonstrations would be to show the limitations of visual guidance in

all visibilities, particularly when disturbing factors are introduced, and not merely to improve the pilot's instrument flying. Some weather conditions, notably shallow or stratified fogs, are specially treacherous in that the sudden decrease in visual range on entering the fog layer looks like a change in pitch in the nose-up sense. Pilots therefore tend to steepen their angle of descent when they enter the fog. However, once a pilot has been shown this effect on a simulator he can guard against it if he has a stable aircraft. As a further safeguard, efforts are being made to report weather conditions in a form which will give the pilot a better idea of what to expect of heights below the critical height.

DISCUSSION

The Chairman (Mr. Peter Masefield), opening the discussion, said that Mr. Pike's mention of the economic problem of achieving regularity on services in bad weather rang a bell in the minds of all who had been concerned in airline operations. A bad period of fog in the early part of the winter could have a catastrophic effect on the traffic during the whole of the rest of the winter because people got the feeling that the services were going to be irregular. With reference to Captain Prowse's remarks about the human qualities of the pilot the Chairman remarked that, while it would undoubtedly be extraordinarily useful if, in the process of evolution, we could breed a species of man with four arms and four legs and two heads to help in the computing process, it was at the same time undoubtedly true that the human "black box" was extremely efficient. It had been estimated that a computer designed to make all the necessary computations to play one side of a game of tennis with precision and accuracy would occupy the space of two tennis courts. The human computer was really very good, when one considered the restricted space available to it.

Captain A. P. W. Cane (B.O.A.C.) said he would like to take both Mr. Pike and Captain Prowse up on one point. They had both emphasised the inability of the human being properly to assess his approach and landing and yet they had followed on by saying that they required some visual means of monitoring a mechanical method of landing so that the pilot considered himself safe. This seemed to him to be a contradiction in terms. If the pilot was given a mechanical device he would be liable to make the same mistakes as he would have made with a purely visual landing and this did not seem to further the process of having an automatic landing.

A lot was heard from time to time about take-off monitors and the emphasis was always on something which would tell the pilot whether he had reached the required speed, commonly known as V_1. It happened quite frequently nowadays that the hazards on take-off occurred after, rather than before, V_1, so that a take-off monitor designed to deal with the situation up to V_1 was not going to be the answer to the problem of take-off in the future.

Mr. Pike, in reply to Captain Cane's first point, admitted that this was a contentious subject and in his experience pilots often disagreed, quite sincerely and violently, about it. But the opinion he had heard expressed most often was that until such time as the pilot had complete faith in a "black box" he would require some assurance, by means to which he was accustomed, that things were going according to plan. One could think of many illustrations of this apart from approach and landing.

On the subject of take-off monitors he thought it was important that the take-off monitor should not be thought of as replacing the pilot's responsibilities in any sense, but as a device for aiding the pilot's judgment in slush on the runway, or other difficult conditions, it was likely to prove very valuable.

Captain Prowse agreed that the first point raised by Captain Cane was controversial. He knew Captain Cane very well and there was no doubt in his mind that the average airline pilot, who was not as technically excellent as Captain Cane himself, did not view these things in quite the same way and required a great deal more reassurance, at least when he was making a start with a new approach and landing operation without touching anything.

He agreed fully with what Mr. Pike had said on the subject of take-off monitors: in his opinion it would certainly make the take-off safer, but it certainly would not answer all the problems.

Captain J. Woodman (B.O.A.C) said that as an airline pilot, he believed that the need for an independent monitor for automatic approach and landing depended very greatly on how soon full automatic approach and landing was realised. He did not believe that they would be realised as quickly as he personally would like and he quoted the view of I.A.T.A. that this would have to be an evolutionary, as opposed to a revolutionary, process. This meant that progress would be gradual, *i.e.* automatic approach and landing would gradually be used but it would not be used in very low visibilities and in bad conditions until the pilot had acquired a feeling of confidence in the equipment. He personally would not like to land in this way in zero conditions, even with an independent monitor, until he had been exposed to it for a long time. In the same way it had been a long time before the I.L.S. indicator had been accepted for a monitor for G.C.A.

T. W. Prescott (B.L.E.U., R.A.E.) said that Captain Prowse had asked for an independent monitor for automatic landing and had mentioned the televiewer but this again was another collection of black boxes. Was he going to trust the televiewer and not the auto-pilot? Was it necessary to consider multiplexing the televiewer as well as the auto-pilot? Or was it possible, if a single-channelled auto-pilot failed at a height of, say, 50 ft., for the pilot to detect it by reference to the televiewer and take over? He thought that the development of automatic landing was more advanced than that of the so-called independent monitors and considered that the right way of introducing automatic landing was to duplicate, triplicate, or multiplicate the auto-pilot. This would provide the necessary safety and the pilots could then carry out automatic landings in weather conditions no worse than they were flying in today, thus building up confidence before using the system in bad weather conditions. In short, he felt that the outside world was a better monitor than another series of black boxes in the form of a televiewer.

Captain Prowse, in reply, said that he felt Mr. Prescott was mixing up the technical side of the question, on which he was undoubtedly an expert, with the psychological side which he himself had stressed and it was a very difficult thing to combine these two different points of view.

Mr. Pike again stressed the psychological aspect and quoted Group Captain Ruffell-Smith's remark to the I.A.T.A. that it was no good designing a system unless you could sell it to the pilot. On the same occasion Group Captain Ruffell-Smith had also made a plea for learning from physiology and not going too far in duplicating or triplicating equipment with the associated complexities; he had drawn attention to the fact that man, with excellent design, had got on very well with one heart and one brain.

The Chairman commented that some people might wish the heart and the brain had been duplicated.

Dr. M. W. Woods (W.R.E., Australia) said that, as a non-pilot who was sometimes a passenger, he would like to agree with the pilots. He did not think that passengers would be very happy to see black boxes doing the job without a man at least keeping an eye on them and as a parallel, but much simpler, case he quoted the one-dimensional problem of driving an electric train. Nothing could be simpler to do automatically or mechanically, but he did not think anybody had seriously suggested that we should have electric trains without drivers. He did not think the passengers would be happy and still less did he think the passengers in an aircraft would be happy without a pilot monitoring the black boxes.

N. C. Green (B.E.A.) suggested that in what had been said about having one set of black boxes to watch another, and the pilot to watch the lot, it might have been overlooked that the human brain found criticism much easier than action. If the pilot were monitoring a nice clear picture on a T.V. screen and monitoring another presentation with an entirely different set of black boxes, he was in a much more relaxed position to detect faults in either and to take action when required. This led him to a second point, which was to ask the manufacturers who designed these things for a certain degree of simplicity in operation: it was the complexities which produced fatigue. He mentioned the case of a foreign observer who had witnessed a demonstration of automatic landing on well-known British equipment, at the end of which he said it was very instructive, but that he had never seen anybody work so hard to avoid touching the control column.

G. W. Stallibrass (M.T.C.A.) said it would be very interesting to hear views on the need for some advance in instrumentation in connection with the problem of take-off. His impression from the outside of the cockpit was that, if anything, the take-off was far more difficult than the approach and landing in the sense that even more had to be done in a shorter time. Secondly, accidents had occurred in the past when a pilot, having just left the runway guidance and gone into the darkness of the night, or atmospheric trouble by day, had been confused by acceleration sensations and by a very small misreading of the artificial horizon, or even an inaccuracy in the artificial horizon itself, and had put the aircraft down. Captain Prowse had mentioned swirl effects, which were said to make a pilot capable of misreading the artificial horizon even when this was accurate and if they now went back to the sensitive air speed indicator they would in fact be going back to something which Captain Prowse had criticised at the beginning of his talk, namely, the blind flying panel, as it had existed 25 years ago. Runways were being designed with better and better guidance, lights and other things, but at a certain stage of the take-off all that was behind the pilot and he had to rely on his instruments.

Captain Cane said it was his experience that nowadays the pilot did not fly on the artificial horizon after a jet take-off; he flew on air speed. If the pilot stuck to his air speed after he had got off he was all right and he need not worry about the artificial horizon. The big problem of jet take-off, a problem built in by the manufacturers, was over-rotation and the inability to take off altogether. He also referred to the pleas made by Mr. Pike and Captain Prowse for slower approach speeds. He agreed that this was a crucial matter and he felt that it could be achieved if the airlines asked in their specifications for lower approach speeds on the aeroplanes instead of asking straight out to get from A to B five minutes faster than their competitors. It could be done; in fact, there was a jet air liner at present flying which had approach speeds as low as, if not a little lower than, some piston-engined aircraft flying at the present time, namely, the Comet 4.

The Chairman remarked that this was a most useful contribution. Much that had been heard during the evening constituted an indictment of the design of modern aeroplanes. This implied an indictment of the manufacturers and designers but equally, he thought, of those responsible for specifying what they wanted in the next generation of aeroplanes and who were not putting enough emphasis on such questions as approach speed. The Comet had just been mentioned as one particularly good aeroplane in this respect; the Vanguard, which was just coming into service, was specified to have an approach speed not exceeding 115 knots and he felt that this was the right sort of thing. The anxiety of the pilot during the approach in bad weather, which Captain Prowse had mentioned, arose because designers and manufacturers had not paid enough attention to this aspect and he would be glad to know if anyone in the audience would like to answer this point from the designer's point of view.

Colonel P. M. Retief (South African Air Force) questioned the point of view put forward by Captain Cane regarding watching an air speed indicator alone on a jet take-off. His experience of jet take-off was that this would have been, on many occasions, absolutely fatal. In his opinion air speed alone was not sufficient; there were many other instruments that the pilot had to look at in order to make a safe take-off.

Captain Cane replied that the present procedure, as far as he knew in all airlines operating jets, was to fly on air speed. This procedure had, in fact, been forced on the airlines by the noise abatement campaigns all over the world. There was a safe air speed, *e.g.* V_2+15, or V_2+10; the pilot accelerated up to that air speed and then held that air speed during the climb for the first 1200 to 1500 ft. He did not ignore the other instruments, but the master instrument in take-off was the air speed indicator.

Mr. Pike referred to a discussion which had taken place on this subject at a recent jet symposium organised by I.A.T.A. He confirmed that the pilots who were flying jets had stated that they were using air speed, exactly as Captain

Cane had said, but it was also fair to say that they were keeping a pretty close eye on the "rate of climb" indicator. In fact, they seemed to be making up to some extent for the deficiencies of the artificial horizon and the difficulty of reading it, by using the rate of climb indicator. Test pilots had emphasised the need to be very careful about when rotation was initiated and subsequently the establishment of a positive and adequate rate of climb. Contrary views had, however, been expressed by other airlines, one of which was flying the Caravelle; they felt very strongly that there was an urgent and valid requirement for better horizon indication. Mr. Pike also referred to the work being done in America on other means of determining angle of attack.

The Chairman said he was not sure whether the completely new presentations of horizon being tried out in the United States were subject to acceleration problems or not, but from what he had seen of them there appeared to be very much more natural presentations than the present artificial horizon.

Flt. Lt. A. J. Camp (B.L.E.U., R.A.E.) said that, as one of the major users of automatic landing he had heard the whole subject of all-weather take-off and landing stated and restated but, at none of the meetings which he had attended had the operators come forward with a firm demand. They tended to get side-tracked on small issues and the manufacturers would not be able to satisfy them until they themselves made up their minds. For example, there were two main systems of blind approach and landing, the B.L.E.U. system and another system using radar, and it was not known whether either of them would become internationally accepted.

The Chairman said it was clear that two completely opposite approaches to the problem were emerging from the discussion, as they tended to do from any discussion of this sort: one was the fully-automatic operation with the pilot monitoring and ready to take over if anything went wrong; the other was to provide a means of enabling the pilot to be more precise when he was lacking the external references he normally expected to find. He would like to pose the question which of these two approaches was really favoured, (*a*) from the manufacturing point of view, and (*b*) from the operator's point of view.

Mr. Pike accepted the point made by Flt. Lt. Camp but he thought it was somewhat unrealistic, since it implied that the operators had a prescience which they did not possess. Systems were produced by experts who studied the subject and it was too much to expect pilots and engineers to give in the early stages of system evolution categorical answers to very intricate questions. He felt it was easier to deal with Flt. Lt. Camp's point by quoting the classic example of approach lights, with which he had been closely involved for something like six years. It was not until Mr. Calvert had pointed out to a group of airline pilots why they liked certain features that they had begun to understand the subject. He felt that the same thing would have to happen with automatic landing devices and it was absolutely right at the present time not to select prematurely one or the other line of approach but to go ahead with development of both methods; there was even a possibility that they might be found to be complementary to each other in the final analysis.

R. E. Young (Sir W. G. Armstrong Whitworth Aircraft Ltd.) referred to the point made by Dr. Woods about driverless electric trains. There was a certain amount of thought going into this subject and there was also an underground railway run by the G.P.O. since well before the war which operated on that principle, with a frequency of service of two a minute from Mount Pleasant to Paddington.

With reference to a televiewer display, it was essential that the input data should come from an entirely independent system if it was to be non-suspect. As regards using a televiewer system as a monitor, he had heard one use of this described as a "tranquiliser" but if it was going to be used to indicate when things went wrong it would probably be too late, with modern speeds as they were, for the pilot to take action by the time he had realised that it had gone wrong. Consequently, if any form of monitor was to be used, he would suggest that it had got to incorporate some form of anticipation. This was not an easy thing to do but he thought that possibly something in the form of a clarified phase advance could be built into the system.

Mr. Pike said he had heard this subject discussed in 1958 at the Flight Safety Foundation Seminar, Atlantic City, and he understood that anticipation could be built in both on the flight-director side and on the prediction side. Work was being done by the U.S. Navy in particular and demonstrations had been given of results from a pilot flying a helicopter with and without it; his performance with the aid of this fast analogue response indication was remarkable. Similar exploratory work was being done in connection with submarine depth control and he had a feeling that this was a profitable avenue to help to improve the aircraft pilot's performance.

PART II

The Chairman asked Mr. Calvert if he thought it would be possible to build a simulator which could give a satisfactory simulation of bad weather approach, putting in to it any visibility required. He was also anxious to know more about the possibility of television through bad visibility, although Mr. Calvert had rather thrown cold water on the subject.

Mr. Calvert said he did not think that people could be trained with simulators for visual landings in good or moderate visibility but they could be shown the pitfalls which might occur in particular situations in bad visibility. The difficulties in building a simulator became greater as one tried to increase the visual ranges simulated. Take for example a simulator intended to work from about five miles out; a small model was necessary and that, in combination with the poor quality of the television picture, produced all sorts of undesirable effects.

The Chairman said that he could not quite understand why it was not possible to have a television camera which eventually would give a complete picture on the windscreen of what would be seen if visibility were better than in fact it was. He had heard that it was possible to get television that would see through darkness to give a light picture when in fact it was dark.

Mr. Calvert said there were flaws in this idea: the picture had a spurious texture, it did not do the right things when the pilot moved his head and it had not got the right convergence for his eyes. In fact the brain was really a kind of computer: what happened was that the pilot

saw a particular situation in his mind's eye and after thinking of many things his mind suddenly said "Ah, this fits, this means so-and-so, I have seen this before"; he then decided to take certain action. The trouble with all this was that when he compared what he saw on the screen with his mental memory of it the two things did not fit in all respects. For instance, the contrast in the television tube was not more than 30 to 1, whereas in real life it was 3,000 to 1. After a while a pilot could perhaps learn to use the television picture but then he would really be learning another instrument presentation. This raised the question of reliability.

Mr. Coombes said that in Australia they had no real experience of the bad weather landing problem. They had concentrated on the problem of landing in the dark with very moderate impairment of visibility conditions. Their development of landing aids was mostly geared to the provision of relatively cheap equipment at a large number of minor airports in Australia; they had done none of the elaborate television or simulator work that B.L.E.U. had done, nor had they done anything in the way of automatic landing except in the case of the Jindivik. He mentioned that in the early 1920s there had been an automatic-landing flying boat at Felixstowe. The device had been called the Cooper Night Landing Stick and consisted of a cross-shaft and a long stick which was let down and on contact with the water pulled back the control column; in this way many successful landings were made. He then asked if more information could be given on the televiewer as an aid to landing.

Mr. Prescott stated that the television technique using a camera in the aircraft was applicable only if the optical conditions were right. In a bad weather landing it was necessary to see through fog or mist and therefore it was necessary to have a radio picture, *i.e.* televiewer. The difficulty then was to provide the necessary resolution on the screen in the cockpit. With the sort of range required this determined the aerial size and aerials of 30 ft. diameter might be required on modern aircraft. There was hope of alternative techniques but these had still to be proved. Captain Prowse had said that even in good visibility conditions landing larger aircraft with increased approach speeds was getting marginal. With a televiewer the pilot was now being asked to do the same sort of thing on a degraded picture. Mr. Prescott was convinced that automatic landing was the coming thing not a televiewer, and that to gain the necessary experience of automatic landing pilots should practise in clear visibility and use the outside world as a monitor.

Mr. Stallibrass suggested that no one had disputed Captain Prowse's statement that until there was absolute reliability in automatic landing one could not expect pilots, or for that matter passengers, to wish to fly under the conditions in which they could rely on that and nothing else. On the other hand they had heard scientists say that it was largely a question of getting experience and that things would be all right in time. If one were asked to state an acceptable landing accident rate one would find that the acceptance of fully automatic landing was years ahead and therefore something must be done in the meantime. If it was correct to say that pilots were near the limit of human capability in operating aircraft manually, the problem was to detect that limit and not to exceed it; in other words one might have to be tied by certain restrictions if the limits of human capability were not disregarded. He also could not agree with Captain Cane in his under-estimating the take-off problem. He was not very reassured when he heard the pilot say, "If we reach 100 knots in 30 seconds we will go," and then reached 100 knots in 28 seconds: he suggested it indicated a certain possible anxiety in the cockpit. He suggested that something more was wanted than a good air speed indicator on the take-off of the present big jet aircraft.

Captain Cane in reply did not agree that he had underestimated the take-off problem. In fact he had said there was a very serious problem especially with regard to over-rotation. He had said that once one was airborne in a jet aircraft the acceleration would take care of things and the main instrument thereafter was the air speed indicator. He had agreed with Mr. Stallibrass that there was a problem about the take-off of a jet aircraft up to the stage of becoming airborne. V_1 and V_R had now come to be the accepted speeds which pilots had to think about because if one rotated correctly at V_R one became airborne. The problem was the question of correct rotation and correct angle of rotation if one were flying one of those aircraft that would not take off if over-rotated.

Mr. Calvert said that Mr. Stallibrass had put his finger on something important. He thought it would be necessary in the future to design to a limit, but to find where that limit was and what sort of vehicle was needed would involve much more operational research. He went on to say that the R.A.E. had spent many years trying to improve visual guidance in the vertical plane in bad weather under the impression that most of the accidents at landing occurred in bad weather. The U.S. Air Force however had investigated 14 million landings in 1953-54 and they had found that in accidents due to visual misjudgments 95 per cent had occurred in visibilities better than two miles. This meant that if the good weather problem were solved by providing visual guidance 95 per cent of the accidents were affected. On the other hand if the bad weather problem were solved only 5 per cent of the accidents were affected. As the good weather problem could be quickly and easily solved by the use of an effective visual glide path indicator, money spent on this would obviously pay a very large dividend in increased safety.

The Chairman thought that one of the important points the discussion had brought out was that it was necessary to examine not only what was required in the way of improved instrumentation and techniques, but also what was wanted in the way of improved aircraft. He liked to think that aircraft would never be as bad as they were now. If one looked ahead towards supersonic transport aircraft, as indeed one must, it was quite apparent that they would have lower wing loadings and the low wing loadings ought to produce better approach speeds. This might be paradoxical but he thought that this was coming. He would like to hear pilots' opinions on what they felt was the minimum they could expect and what ought to be specified as a sort of standard to be achieved.

Captain Prowse in reply could make no specific suggestions but stated that although during the past ten years there had been much talk about these things, in fact approach speeds had got steadily worse. He felt that the manufacturers knew what was wanted but that, perhaps because speed was emphasised, the pilots did not get what they wanted.

The Chairman commented that the possible advent of V.T.O.L. before long would introduce a very different approach.

L. F. Nicholson (D.G.S.R.(A.), Ministry of Supply) taking up the point about supersonic aircraft, stated that at present there was a tendency for approach speeds to go up and up since, other things being equal, it was cheaper to operate an aircraft with a higher landing speed. He emphasised however that it was not just one of the scientific facts of life that things must get worse and worse. He felt strongly that there were some existing subsonic aircraft which were far worse than a supersonic aircraft need be, provided the latter was designed with the right compromises between the landing problems and the general economics.

Dr. G. V. Lachmann (Handley Page Ltd.) stated that he wished to make a contribution on the question of lower approach speeds and lower wing loadings. Wing loadings had gone up because it would not have been possible otherwise to produce large and fast aircraft. They now had modern jet air liners with wing loadings of the order of 100 lb. per sq. ft., whereas he remembered how shocked they had been at Handley Pages when they produced the Hampden with a wing loading of 20 lb. per sq. ft. which was twice that of the H.P.42. He suggested that although everyone had got used to the higher wing loadings the people who had really been badly treated were the pilots. He then went on to mention boundary layer control, of which there were two different forms, one for high lift and one for low drag. Great expectations had been placed on the high-lift boundary layer control to give high lift coefficients, lower landing speeds and better take-off but this technique had been a disappointment in certain respects. The other form of boundary layer control for low drag was accredited with reducing operating costs because of the L/D ratio. If it were possible to produce low drag aircraft one could afford to have relatively larger wings than on conventional aircraft, since it had been the drag penalty which had forced designers of modern aircraft to reduce wing areas. It would therefore be a deliberate reversal of focus to go to the lower wing loadings but these could be compensated for by the lower drag on the wings. He suggested therefore that the outlook was not completely bleak and that there were ways and means by which the aircraft designer could improve the present situation.

The Chairman commented that they had now heard two points of optimism, one from Mr. Nicholson and one from Dr. Lachmann, and that designers would certainly have to give this subject careful thought.

J. Deakin (Sir W. G. Armstrong Whitworth Aircraft Ltd.) wished to comment on the point made in Mr. Coombes' paper about the answers to the pilots' questionnaire. He suggested that the basic problem in landing was to arrive at a certain place safely, and he had found that some pilots did circuits before landing and others preferred to make a straight approach. He had recently been concerned with tests where an aircraft had to obey a certain pattern before landing; the tests were to show compliance with certain Air Registration Board regulations. The pattern on which the aircraft were flown had not been necessarily the pattern which the pilots flying the aircraft would fly of their own choice and to make their own preferred landing in any given condition. He wished to make a suggestion that might raise some comments from Air Traffic Control, and possibly from pilots, which came halfway between completely automatic landing and completely visual landing. The suggestion was that the aircraft would arrive at a certain point at the end of a runway at a certain altitude, to be arranged by radio marker beacons, and then the pilot would inform Air Traffic Control of certain aircraft conditions including the aircraft weight. Air Traffic Control could then feed into a computer the type of aircraft weight, airfield temperature, airfield altitude, and so on, and then relay them back to the pilot so that he could then fly the aircraft at the right rate of descent and at the right speed to enable him to complete the landing. In this kind of landing the pilot, although he would be obeying instructions, would be in complete control all the time.

Mr. Pike, commenting on this suggestion, thought that this was not at present the way to go about solving the problem. He thought that Air Traffic Control already had a very difficult job in performing its main function of facilitating the flow of traffic and avoiding collisions. He did not favour increasing the volume of air/ground communications nor did he favour taking too much judgment out of the cockpit. He thought the initial reaction in the early days against G.C.A. was for this particular reason and, having listened to many pilots on this subject, he favoured leaving the manipulation of the aeroplane to the pilot's judgment until the day arrived when the whole thing could be done fully automatically.

J. E. Hutchinson (Royal Aeronautical Society) said that he wished to suggest another point of optimism and that was on the question of reducing approach speed. He understood that tests had been done in the U.S.A. on thrust reversers, not only using them to reduce the landing run but also to control the approach. He also suggested that it would be a great advantage to have an angle-of-attack indicator in the cockpit to assist the pilot on the take-off run in judging the rotation and also during the approach, when the pilot would be able to see just how much he would have to pull back the control column to align himself on the runway. A further development might be that if a pilot knew the actual weight of his aircraft it could assist him in the selection of approach speeds under critical conditions.

A. C. Campbell Orde suggested that there was no new problem here and, in connection with Mr. Calvert's introduction, he felt that the problem would not be solved merely by reducing approach speeds back to what they had been five or six years ago. He thought that the most important point made by Mr. Calvert was the need for operational research. Ever since flying began these sort of problems had existed and had been dealt with piecemeal by one or other method and that was not now good enough. He suggested that B.L.E.U., for instance, required more guidance since they were anxious to help operators and users, either military or civil. He thought that this was a very useful meeting since those present included not only pilots but representatives of quite a large number of different interests from different parts of the world. It was only by a comprehensive attack on the problems that they would get the right answers and, incidentally, in the process, avoid discarding possible solutions at too early a date.

Mr. Calvert, in support, fully endorsed the need for comprehensive operational research. He felt it was

essential that the very best people should be employed in it.

K. G. Wilkinson (B.E.A), commenting on the approach speed problem, suggested that there was a danger, if this particular problem were singled out, of ensuring that they got aircraft which were not going to go down in history as successes. He was interested in what Mr. Nicholson had said about the supersonic aircraft since he had not realised from what he had read that they were likely to be so good from this particular point of view. He thought that the conclusion that could be drawn from the aircraft built since the war was that if one particular thing were singled out, regardless of all the other items in the equation, one might achieve something which was perhaps an improvement from the pilot's point of view, but in the ultimate analysis was unlikely to achieve enough to offset what it cost. He thought that the same thing applied if, instead of just using wing loadings to reduce landing speeds, one went in for rather complicated systems such as boundary layer control.

Captain Woodman, apropos of what Mr. Campbell Orde said, thought that nobody had yet given proper credit to the television trials that had taken place. Mr. Calvert had explained that with the sort of resolution that might be achieved the televiewer would not be practical. He did know, however, that the pilots who had flown with television flew quite well on it the first time. In spite of the statement by Mr. Prescott that an aerial of 30 ft. diameter might be required, he thought that if the same type of presentation could be produced by radio picture, it might be that the visual approach indicator as developed by the Australians would lend itself to that treatment and could be used with that sort of picture.

The Chairman asked if anyone would care to comment on the angle-of-attack point since he thought that this might be helpful in the problem of rotation.

Flt. Lt. Camp stated that at B.L.E.U. they had flown at controlled air speed below the minimum drag on the approach. They had tried angle-of-attack and found that even well below the minimum drag the signal they were working with was far too small; on normal approaches they were working on a relatively small change of incidence for angle-of-attack and they found it was not possible to control the angle-of-attack directly with the throttle. As for the rotation on take-off he stated that civil operators used a different technique from the R.A.F. who did not have this rotational problem, because R.A.F. pilots were permitted to lift the nose off before V_1.

W. G. F. Burns (Australia House), commenting on the optimistic statements which had been made about approach speeds, said he took cold comfort from a recent statement attributed to the F.A.A. in the U.S.A. suggesting that they would refuse to certify an aircraft requiring runways in excess of 15,000 ft.

Mr. Young, on the question of the televiewer, asked if B.L.E.U. could state the number of landings that had been achieved using the television technique. He suggested that since the televiewer might need only passive equipment on the ground, it might offer some solution, particularly in the cases where aircraft were operated from airfields where there were no extensive servicing facilities. One of the main troubles with "black boxes" in the past had been poor maintenance.

Mr. Prescott, in reply, thought it might be wrong to assume that televiewers would only need passive elements on the ground. There remained the question of using the televiewer in a bad weather landing and in this connection he referred to pilot anxiety mentioned previously by Captain Prowse. In the television trials they had conducted at B.L.E.U., a safety pilot was on board and that was bound to have an effect on the pilot doing the task; if he made a mistake he knew there was somebody else who could see and take over the landing from him if necessary. He believed this aspect had a significant influence on the experiments which they had made.

Captain Cane said that he had had considerable anxiety when flying with the television but he thought there had been some confusion at this meeting between television and the televiewer. Flying by television in daylight the pilot was presented with texture and a simple means of landing, but once he got down to seeing what were, in effect, a set of runway lighting he had no texture and he was in landing difficulties. A further point he made concerned the reactions of a pilot doing a blind landing automatically monitored by a televiewer; the pilot would be in a quandary if, despite all the indications appearing to be correct, he felt that in fact the picture in the televiewer was incorrect.

The Chairman invited the four lecturers to make any final comments.

Mr. Pike mentioned the question of windscreens. For instance the difficulty of removing rain of the tropical variety from the windscreen when making a night landing had been discussed many times and he would like to suggest that designers in the Aircraft Industry should give more serious thought to the problem of keeping the windscreen clear: wipers were not entirely satisfactory.

A further point he made was that in system design they should cater for the pilot a little below the average rather than the highly qualified technical pilot. Every pilot at one time during the year was probably below average. He did not wish to criticise B.L.E.U. but he thought one should be cautious in assessing results carried out by highly qualified, very experienced pilots. Many airline pilots probably only made one or two bad weather landings a year, and he felt that it was their reactions which were most important to discover. In endorsing Mr. Campbell Orde's plea for more integrated research effort, he felt that the average airline pilot's views should be considered in such effort, and not just bring him into the picture at the end of the design activity.

Captain Prowse was pleased that his point about the pilot reaching his limit had been taken, and he too endorsed Mr. Campbell Orde's suggestion for a really co-ordinated operational research effort. As to the televiewer, he thought that it had to be used as a tranquiliser to reduce the anxiety of the pilot. He hoped that simulators would be available for practice since practice was all-important in keeping pilots proficient.

Mr. Coombes, on the question of operational research, said that in Australia they had not had the advantage of a specialised flight such as B.L.E.U., but perhaps in some ways that had been an advantage. They had had to use

a large selection of pilots from the various airlines, and so they got a pretty fair cross-section in their investigations. Beyond that, of the two scientists chiefly concerned with this work, one was a pilot and the other had actually taken a pilot's training and had got his " B " class licence, so that they could fully appreciate the pilot's point of view.

Mr. Calvert had been pleased to hear of the support given to the plea for more operational research. Concerning the televiewer, one of the troubles when using the television technique had been in analysing the final tests and, as Mr. Pike had pointed out, the use of skilled pilots could be misleading. Operational landing systems must have a very low failure rate, say two in a million, and this could not be accurately assessed in pre-operational flight tests. Therefore, he thought that comprehensive operational research was required. On the question of windscreen obscuration he said that was one reason why they had gone over to a coloured V.G.P.I.

The Chairman, in summing up, thought that they had gone as far as they could on the subject for that evening. There had been a most valuable discussion and he wished to thank, on behalf of everyone, Mr. Pike, Captain Prowse, Mr. Coombes and Mr. Calvert and the 26 people who had contributed to the discussion. He thought that they had exposed a number of things which required a great deal more thought. Many of these things had been discussed over the past 10 years at I.A.T.A., and I.C.A.O. and all over the world, but still there was a lack of precision in what was trying to be done. He agreed with Mr. Campbell Orde that we had to get some real precision into this search for the solutions which could only come from having better operational research. He was sure that this aspect of Aviation was too marginal, since decisions had to be made sometimes in anxiety and therefore could only be partially satisfactory, but this was no indictment on the pilots. He thought it was an indictment on the designers and manufacturers and they must recognise this very clearly.

He also suggested that a great deal more needed to be done on instruments. Although a certain number of people were working on this subject the presentation of instruments had not really been improved vastly in 30 years.

He was convinced that the supersonic transport aircraft was bound to come. Whether or not it would be a good thing, and whether or not it would be economic was debatable. But the die was cast. V.T.O.L. would certainly be established shortly in the military field, and this would inevitably lead to civil use later on. This would bring on all sorts of new problems of approach and landing, to say nothing of take-off, and he would like to believe that such problems would never be worse than they were on present day aircraft. Nobody today had mentioned the jet flap which he thought had possibilities, but there had perhaps been enough in the recorded discussion to show what was generally required.

In conclusion he thanked the Commonwealth Advisory Aeronautical Research Council for the initiation of the Symposium, and also thanked all those who had attended.

The Australian View

by

R. W. CUMMING

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IN both civil and military flying take-off and landing accidents represent a major part of all accidents. In both take-off and landing, the problems are becoming more acute with the current change to larger and faster aircraft, and even more significantly with the change to jet engines.*

The majority of accidents occurring in these two phases of flight are attributed to " human error," or " pilot's error of judgment," but recent human engineering studies have shown that in many cases the real cause has been due to the engineering situation overloading the pilot in some way, or requiring him to make judgments based on insufficient information. In the review which follows both the take-off and landing problems are considered under the headings: human problems, aerodrome problems, aircraft problems, and instrument problems. There is however considerable interaction between these groups, and it will be seen that many of the problems listed can contribute directly or indirectly to " pilot error " accidents.

*U.S.A.F. accident figures for the years 1953-1954 show an undershoot accident rate of 52 per million landings for jets compared with 7·4 per million landings for piston-engined aircraft.

Take-Off

HUMAN PROBLEMS

Perhaps the most difficult of the human problems in take-off with the new jet aircraft is the judgment of whether the acceleration on the ground run is adequate for a safe take-off, or whether the take-off must be abandoned. A decision to abandon must be made sufficiently early in the run to allow for stopping in the remaining runway length. This judgment has become more difficult due to a combination of the thrust/speed characteristics and the temperature sensitivity of jet engines.

This has led to a requirement for the development of new techniques and instruments to allow the pilot to monitor the acceleration on the ground run and to keep a

constant check on the thrust being delivered by the engines. It has also led to the need for extensive retraining of pilots in the changed performance characteristics of jet-engined aircraft.

The classical night take-off problem of sensory confusion between acceleration and climb, which has caused many accidents, can be accentuated by the increased acceleration, higher speeds, and in some cases, lack of control feel, of jet aircraft. Thus, in the absence of external visual cues, as experienced on a dark night, the pilot must be trained to ignore strong sensory illusions, and adequate instrumentation must be provided. Development of angle of attack indicators is one solution to this problem.

A further problem is the use of power controls, which also calls for more instruments.

AERODROME PROBLEMS

Adequate centre line marking is required to give the pilot steering guidance during the ground run, and marking and lighting of one or more distances along runways may be required in order to allow him to monitor his ground run acceleration.

A major problem with jet aircraft, particularly those with low slung engines, is the requirement to keep runways scrupulously clean, and free of all loose objects. Another problem is the need for runway surfaces to withstand the heat from the jets, and from the heating and chemical effects of spilled fuel.

For maximum braking in the event of an abandoned take-off, surfaces must be developed which provide adequate friction coefficients even in the presence of water or snow.

AIRCRAFT PROBLEMS

Drag-speed characteristics of the aircraft must be matched to the flat thrust-speed characteristics of the jet engines. A steep drag rise with fall in speed (as in a partial stall) interferes more drastically with acceleration than with propeller-driven aircraft. The curves of Fig. 1 illustrate this point. It is seen that acceleration with the jet falls off immediately the speed falls below V_{MD}, and this can fall off to zero acceleration rapidly, especially if the lower end of the drag curve is steep. With the propeller-driven aircraft speed can fall about 15 per cent below V_{MD} before acceleration is impaired.

The use of powered controls combined with the critical effect of errors of angle of attack on climb away acceleration make it necessary to provide the pilot with means of knowing accurately the angle of attack and the effect of his control movement on it. Development of both angle of attack indicators and methods of producing artificial feel in powered controls are required.

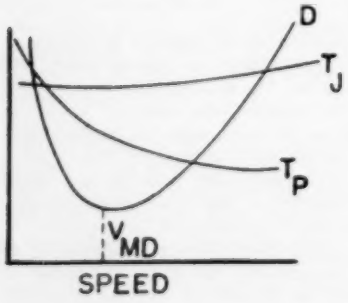


FIGURE 1.

Again, one of the critical features of take-off is the requirement to stop in the remaining runway in the event of an abandoned take-off. In the absence of propellers to create drag, and with slow die-away of jet thrust the development of means for reversing the thrust or a least of destroying the unwanted thrust is of prime importance. For the same reason satisfactory anti-skid devices for maximum braking are required.

INSTRUMENT PROBLEMS

The following new instruments are required for take-off with the new family of aircraft:

Acceleration monitor: this may take a variety of forms, but basically requires the setting in of aircraft weight, runway length, temperature and pressure altitude, and gives the pilot either information on the progress of the acceleration run relative to the minimum required, or a warning if the acceleration is insufficient.

Thrust loss warning system: this is especially needed in aircraft with fuselage mounted engines, where the loss of thrust of one engine is not felt as an asymmetry by the pilot.

V_1, V_2 and maximum take-off weight computer: because V_1 and V_2 depend upon the actual loaded take-off weight and because maximum take-off weight is affected by any change of ambient temperature subsequent to flight planning, it is necessary to provide the pilot with ready means of computing these values in the cockpit.

Landing

HUMAN PROBLEMS

The most serious problem in the landing phase is the difficulty of the judgments which the pilot must make to assess his position and direction of motion on the approach in conditions when naturally available visual cues (*e.g.* horizon, texture of trees or buildings, and so on) are lacking, due either to darkness or restricted visibility or to flight over water or featureless terrain. A further difficult judgment is required during the round-out and touchdown phase, when the pilot must judge accurately his height and flight path relative to the ground, which in some circumstances cannot be seen directly and whose position is only poorly defined by runway lights.

These problems of visual judgment, which account for more accidents than any other single cause, are the subject of active research programmes in the U.K. and in Australia, as well as in the U.S.A. From this work the following results should emerge:

1. An understanding of the circumstances when judgments are difficult.
2. Pilot training to appreciate limitations of visual judgments in some circumstances, and to make best possible use of available visual cues.
3. Design of means to supplement naturally available cues such as instruments in the cockpit or devices on the ground (such as lights, markings, and so on).

The trend to development of fully automatic landing systems has introduced another serious human problem. Inevitably these systems call upon the pilot to monitor their operation, and to take over in case of malfunction. This poses a very great strain on the pilot, who is thus expected to be able to cope with an emergency situation and to execute judgments possibly more difficult than would otherwise be expected of him, without the benefit of constant practice.

Since the new aircraft are landing-length critical, optimum use must be made of the runway length available for landing. This calls for reduction of the variance of touchdown point and energy at threshold, *i.e.* closer control of height and speed at threshold. New guidance means, such as the Australian "Precision Visual Glidepath" or U.K. "Angle of Approach Indicator" give guidance on height at threshold, but pilot training is required for appreciation of the need to cut variance of threshold speed to the minimum. The use of a mandatory threshold cut-off speed is required, *i.e.* the pilot overshoots if his speed at threshold (or over the fence) exceeds a certain value.

AERODROME PROBLEMS

Of prime importance in landing operations is the marking and lighting of aerodromes, and the provision of supplementary visual aids where required, in order to assist the pilot in making his judgments. At present considerable thought is being given to the whole problem of marking and lighting, in many countries, with the effort being co-ordinated by the Visual Aids Panel of the International Civil Aviation Organisation. Contrary to popular belief, problems of this type exist in conditions of moderate to good visibility, by day and by night as well as in poor visibility conditions.

One outcome of the critical landing-length characteristic of the new aircraft is the need for emergency arresting gear in case of misjudgment or braking troubles causing the aircraft to over-run the runway. Systems based both on aircraft carrier hook and cable experience and on nylon nets have been tried and are under development.

The requirement to make maximum use of expensive runways has led to the need for high speed taxiway turn-offs, with the consequent need for development of adequate visual guidance onto them for operation in all visibility conditions.

AIRCRAFT PROBLEMS

As has been mentioned earlier, it is essential that the approach speed be kept to a minimum if the ground run is not to be excessive, since no ready means exist for "washing off" excess speed. The speed at which the pilot is prepared to make the approach depends not only upon the maximum lift coefficient but also upon the stall characteristics, the thrust–drag–speed relationship, lift–drag–pitch attitude–speed relationship, the stability and control characteristics, the responsiveness to throttle changes, the overshoot characteristics of the aircraft, and engine-out considerations. Thus aerodynamics effort put into, for example, increasing $C_{L\,max}$, could possibly be wasted unless accompanied by efforts to improve some or all these other parameters.

The relatively sluggish response to throttle changes of the jet aircraft may be attributed not only to the inertia in the engine but also to the absence of slipstream over wings and control surfaces. One approach to this problem is to develop effective spoilers or thrust deflectors so that the approach may be made at an open throttle setting, with quick changes of drag or thrust available to the pilot. This has the disadvantage of making the approach (which is usually long and low) at high power and hence with increased noise, so that this control requirement itself tends to reinforce the need for noise suppression.

When discussing stopping from a discontinued take-off the need was outlined for improved means of deceleration. Owing to the shape of the landing length–payload curves for jet aircraft, very great gains in landing weight may be made by either an increase of runway length or by more effective means of deceleration. Since a relatively large proportion of take-off weight is fuel, which is used up before landing, this increase of landing weight represents an even greater percentage gain in payload. Clearly it is in the aircraft designer's interest to develop effective thrust reversal means, to be used on the ground run in addition to non-skid braking. For wet or iced runways the aircraft would then suffer minimal landing weight penalty.

INSTRUMENT PROBLEMS

With the ultimate aim of all-weather operations, the development of fully automatic approach and landing systems is highly desirable. An over-riding requirement is reliability, and until this is proved, care must be taken not to overload the pilot as monitor.

However attractive the concept of the fully automatic landing might appear the fact is that, due to cost and complexity, it is only likely to be available at a limited number of airports, so that the pilot must still be able to land the aircraft by more conventional means. Considerable work has been done in U.K. and U.S.A. and elsewhere on the development of integrated instrument systems which take information from many instruments and present it to the pilot in a form which is readily assimiliated. This is of particular importance on the approach to landing when the pilot of a modern aircraft is highly loaded and cannot spare the time nor risk the possibility of errors involved in integrating mentally the indications of a large number of instruments. One instrument of this type has been suggested, in Australia, for assisting the pilot in the visual judgments he has to make on the approach. An experimental prototype is being built and, if successful, will assist the pilot in both good and poor visibility conditions.

The requirement for better control of air speed on the approach leads to a requirement for improved air speed presentation to the pilot (such as in the auditory system developed by the R.A.F. Institute of Aviation Medicine) or for automatic speed holding devices. The latter system would then allow the pilot to concentrate on control in glidepath and azimuth. A logical development is the direct provision of angle of attack or $C_L/C_{L\,max}$ information and instruments for this purpose are under development.

One problem on the approach which has aroused widespread attention, but is not yet solved, is the tendency to misread the standard altimeter—often with disastrous results.* Although human engineers as long ago as 1949 established the desirable principles for altimeter presentation, a completely satisfactory unit has not yet become available, and the majority of aircraft are still fitted with the old three pointer type instrument.

Yet another altimeter problem is the position error, which can be very large in the approach configuration of some of the new aircraft types, particularly if large changes of pitch attitude are involved. The use of radio altimeters for height above ground is a solution when approaching

*In the past 5½ years the U.S.A.F. has had 28 accidents known, or strongly suspected, to have been caused by misread altimeters, and it has been estimated that between 1949 and 1957 thirteen civil and two military Lockheed Constellations were lost in which misread altimeters were known or strongly suspected to be the cause.

over water or smooth terrain, but these do not work satisfactorily over rough terrain, or built-up areas.

Conclusions

Take-off and landing are probably the most critical phases of flight, since they involve operation of many parts of the system near to limits. Moreover, the control of many of these operations is dependent upon the pilot's judgment, so that much attention must be paid to his task; he must be provided with adequate information in the right form; he must not be overloaded mentally or physically; and the system must be designed so that variations of judgment do not result in critical situations. The introduction of jet aircraft has posed a number of new problems as well as aggravating existing ones.

It is seen that there is considerable interaction between the human, aerodrome, aircraft and instrument problems, all of which react upon the performance of the whole system. Thus, it is important that the concept of the "system approach" be followed in research and development work, whether it is in the development of marking patterns for aerodromes or boundary layer control devices for high lift. Shortcomings in almost any phase of the operation can be responsible for, or contribute to, an accident of the type usually attributed to "human error."

Operational Problems in South Africa: The Regulatory Authority's Approach

by

Dr. A. J. A. ROUX

(*Executive Delegate for South Africa*)

Introduction

BEFORE any aircraft type is granted a certificate of airworthiness its performance characteristics are accurately determined and, for large aircraft at least, scheduled in an approved flight manual. Superimposed on these data are certain basic performance criteria which usually limit the operational weight with altitude and temperature, and these limitations apply under all operating conditions.

In order to ensure a satisfactory level of safety for daily operation under varying conditions it is necessary to apply an operations code which takes into account other parameters such as:

(*a*) runway surface, gradient and length,
(*b*) obstructions in the take-off and landing flight paths,
(*c*) obstructions *en route*.

The operations codes are established by the appropriate State regulatory authority and are by no means universally standard. The code used for domestic operations frequently varies from that used for international operations and may take into account the conditions which are peculiar to a State. As far as international operations are concerned the International Civil Aviation Organisation has introduced standards but there are variations in the quantitative interpretation thereof.

Small aircraft are usually operated from airfields where accurate information concerning the physical conditions which may affect their performance is generally not available, and in South Africa the operating requirements for these aircraft contain no quantitative margins.

The operating requirements for the larger aircraft do contain quantitative margins and although the operator may consider that this system of control imposes economic burdens it is generally accepted.

Economics and safety are not always compatible and any operations code is a compromise between the requirements of the operator and those of the controlling authority.

This paper deals only with problems associated with the operation of large aircraft.

The South African Problem

The Union of South Africa and South West Africa, because of their natural topography and physical conditions, present the operators and the Civil Aviation authorities with a number of problems.

A brief survey of terrain heights and airfield altitudes south of 22° latitude is interesting and discloses that approximately 12 per cent of the land area occurs at altitudes between 4,900 and 6,000 ft. and about 43 per cent lies between 3,300 and 4,900 ft. Approximately 72 per cent of the route mileage in the national network is over terrain varying in height between 3,300 and 4,900 ft. and 17 per cent between 4,900 and 6,600 ft. Mountain escarpments are also interposed on many of the routes.

The general terminus of this network is at Jan Smuts Airport which has a runway elevation of approximately 5,550 ft. and the terminus in South West Africa is at Windhoek which also has a runway elevation of about 5,550 ft. Both these airports experience high ambient temperatures during the summer months of the year and Figs. 1 and 2 give some idea of the temperature deviations from standard. The temperature lines in these graphs

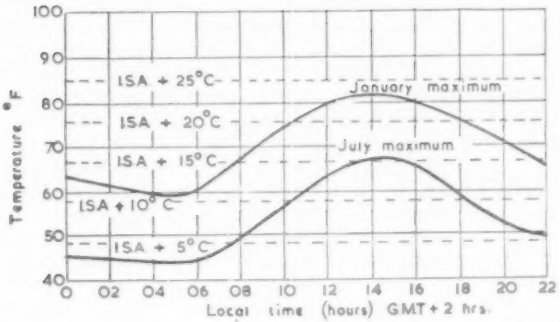


FIGURE 1. Jan Smuts Airport. Hourly variation of ambient temperature based on an 85 per cent probability of not exceeding this temperature.

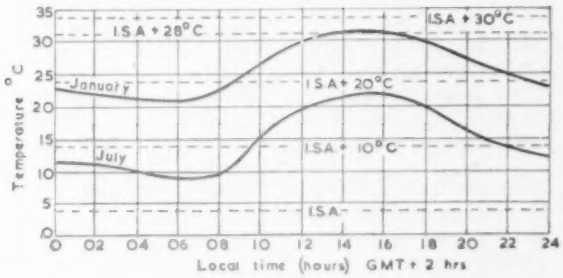


FIGURE 2. Windhoek Airport. Hourly variation of ambient temperature based on an 85 per cent probability of not exceeding this temperature.

have been designed to give, during the hottest and coldest months of the year, an 85 per cent probability of not being exceeded.

Although not unique to the Union of South Africa the main problems which have to be dealt with are the result of:

(*a*) high altitude aerodromes,
(*b*) high ambient air temperatures,
(*c*) obstructions in take-off and landing flight paths,
(*d*) high *en route* terrain.

The first two conditions require either extensive runway systems or reductions in operating weights to permit safe operation. Most airports are constructed by the State and extensive runway systems require large State expenditure which can seldom be fully recovered. The alternative may result in uneconomic airline operations.

The operator may partly overcome the temperature difficulties by taking advantage of diurnal variations but this is not always expedient.

The third and fourth conditions usually act purely as economic brakes because take-off and landing weights have to be reduced to enable fixed safety standards to be maintained.

The following paragraphs deal with the problem of controlling the take-off and landing weights of aeroplanes in such a way that the operation under any set of conditions is both safe and economic. The parameters to be taken into account are the take-off and landing areas available, their altitude, and air temperature, wind speed and wind direction at the time of take-off or landing.

Take-Off and Landing Problems

PISTON-ENGINED AEROPLANES

In the Union and South West Africa during the early years in aviation, aircraft were small and simple and airfields quite adequate in length, so that take-off and landing were no problem. Although the data supplied to the operator were applicable only under standard sea level conditions the only limitation usually observed by him was the maximum permissible structural weight.

When larger aircraft of U.S.A. origin were imported into the Union in 1946 they were equipped with operation manuals which were designed to enable the operators to comply with the U.S.A. Civil Air Regulations current at that time. These manuals embodied certain minimum airworthiness climb requirements which imposed limitations with altitude on the take-off and landing weights. These aircraft were not long in service before operators requested increases in the take-off weight for certain high altitude airports. The position was investigated at that time and higher take-off and landing weights were granted for specific aircraft types operating from individual airports up to certain limiting density altitude conditions. While this system of control was in use no accidents which could be attributed to performance deficiencies occurred, but the operator was left somewhat uncertain of the position at temperatures above standard. The authorities were thus faced with the problem of developing a system of weight control which would satisfactorily combine safety and economics under all conditions. The solution appeared to lie in establishing a maximum take-off weight limitation by factoring down the U.S.A. second segment climb requirement of $0{\cdot}036V_{s_1}{}^2$* (the most critical segment, which was quite restrictive at altitude) and applying full temperature accountability. This principle was finally accepted and its net effect was to establish a fixed rate of climb and maintain this rate of climb at all altitude and temperature combinations by means of weight control.

A weight control graph applicable to the Douglas DC-4 at Windhoek—a very critical airport—is given in Fig. 3.

A landing weight limitation was also established by factoring down the U.S.A. approach configuration baulked landing climb requirement of $0{\cdot}07V_{s_0}{}^2$†. No temperature accountability was applied as the factoring down was considered satisfactory in itself because the traffic densities in the national network are of a low order.

From an operations point of view, however, the above ruling is satisfactory only for airports with no obstacles in the flight path. It does not cater for obstacle clearance planes which exceed the minimum climb gradient obtained from the factored climb requirement. This shortcoming led to the development of an operations code whereby the weight of the aeroplane would be limited so that it is capable of:

(*a*) taking off and reaching a height of 50 ft. or landing from a height of 50 ft. within the take-off or landing distances available;
(*b*) clearing all obstacles in the take-off and approach flight paths by a suitable margin which, in the case of the take-off, is variable and depends on

*V_{s_1} is the true indicated stalling speed or minimum steady flight speed (in m.p.h.) with engines idling, propellers in position normally used for take-off, and aircraft otherwise in the configuration in connection with which V_{s_1} is being used.

†V_{s_0} is the same as V_{s_1} but with the aircraft in the landing configuration.

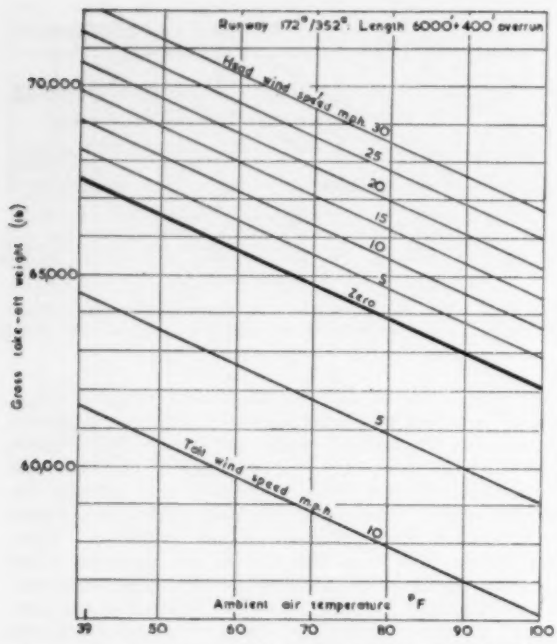


FIGURE 3. Chart of permissible gross weights for Douglas DC-4 aeroplanes at Windhoek Airport for take-off in the northerly direction with ambient temperature and wind accountability.

the distance the aeroplane is away from the threshold of the runway at which the 50 ft. height is required to be attained.

The code developed was based on the recommendations made by I.C.A.O. at that time in their Annex 6, but was modified to include the effect of temperature. It was difficult to implement as the performance data presented in the manufacturers' operation manuals did not include the effect of temperature in all phases of flight and, in the case of several older aircraft types, no performance data was available at all in suitable form.

This difficulty was overcome by local production of flight manuals which were designed to fit in with the requirements of the code and which contained temperature as a parameter.

An avenue which has not yet been explored but which would permit the operator higher take-off weights without lowering the general level of safety is that of unbalancing the field length and thus taking advantage of additional take-off area which could be declared suitable by the airport authority. The mechanics of this system are more clearly dealt with in the following section under turbo-propeller aeroplanes.

Although it may appear from this paper that there are no more problems to be solved, this is not the case. The operator would like to get away from the complicated weight control resulting from air temperature effect because this makes it necessary to schedule the load for individual flights at short notice or to accept weight penalties by using declared air temperatures.

TURBO-PROPELLER AEROPLANES

When a fleet of Viscount Model 810 series aeroplanes was introduced in the Union to replace the Douglas DC-4s for operations on national and regional services, the operator requested improvements at many airports in the network. The authorities were therefore faced with the problem of determining to what extent the existing facilities could be improved to meet the requests made and at the same time to keep costs as low as would be consistent with safe operation.

I.C.A.O. in their Annex 6 have recommended that member States, if they so desire, adopt the principle of declaring stopways and clearways, such as is set out in their recommendations in that annexure.

The manufacturers of the Viscount aeroplane have made provision for the unbalancing of field lengths, thereby giving operators a wider choice of take-off weights from certain airfields.

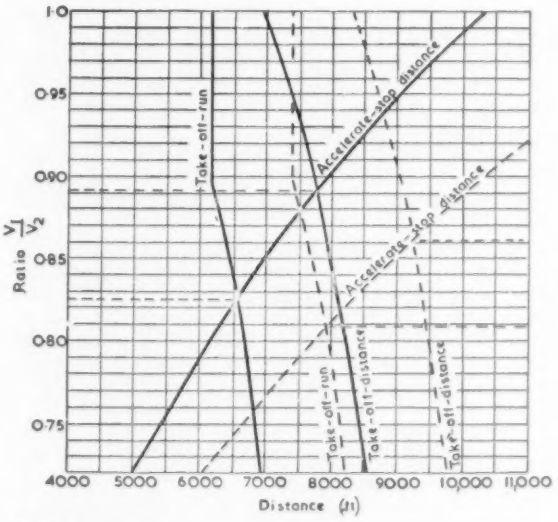
As certain economies can be effected by planning aerodromes on the above-mentioned basis the airfields at Keetmanshoop, Alexander Bay and George as well as Windhoek airport were assessed and an analysis of Windhoek airport for the critical sectors, Windhoek-Cape Town and Windhoek-Jan Smuts, is given below.

Analysis of Windhoek Airport

The following physical conditions are present at Windhoek Airport:

Airport altitude	5,578 ft.
Main runway length	6,000 ft.
Runway surface	Tar
Runway slope	1 in 150 falling towards the north.

Air temperature and wind data are as follows.



Conditions:

Take-off weight: 66,400 lb.	Runway slope: −1%
Runway elevation: 5,560 ft.	Water methanol injection
Ambient temperature: I.S.A. + 28°C	Take-off distance factor: 1·0

Note: (*a*) Weight requested by operator: 67,500 lb.
(*b*) Weight limited by W.A.T. curve.
(*c*) ——— Plotted for no wind
(*d*) — — — Plotted for factored tailwind 6·7 m.p.h.

FIGURE 4. Windhoek Airport. Viscount 810 series aeroplane (Rolls-Royce Dart model RDA 7/1 engines. High activity propeller.)

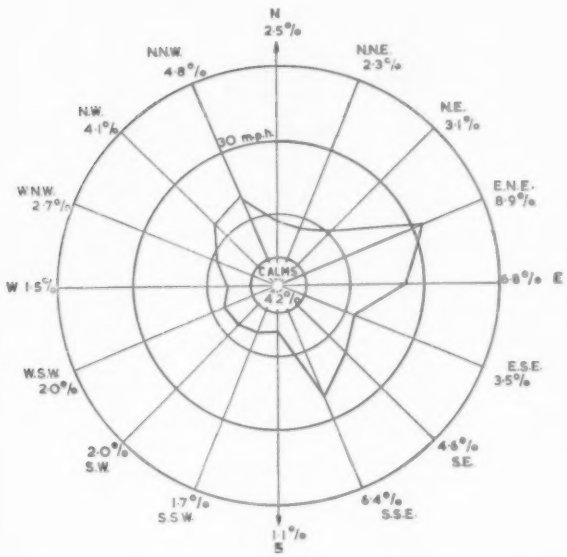


FIGURE 5. Windhoek Airport. Percentage frequency of surface winds as calculated from hourly observations over period August 1948 to December 1950.

Air temperature. Windhoek Airport normally has high ambient air temperatures for the whole year, the temperature seldom being equal to, or less than, that in the standard atmosphere. Fig. 2 is a plot of the air temperature during a 24 hour cycle for January, the hottest, and July, the coldest, month of the year.

Wind is a problem at Windhoek Airport and this can be clearly seen from the wind rose given in Fig. 5. Briefly the airport experiences for about 28 per cent of the time a wind with a southerly component greater than 7 m.p.h. This means that for approximately 28 per cent of the time a tailwind with a component greater than 7 m.p.h. is experienced as the airport is for practical purposes limited to take-off in a northerly direction due to mountains and high ground being present around the airport.

In order to have a clear picture of the possible combinations of runway, stopway and clearway which can be used, the take-off run, accelerate stop and take-off distances have been plotted for a wide range of V_1/V_2 ratios.* These plots appear in Fig. 4 and are for the following conditions:

(*a*) Ratio of V_1 to V_2 ranging from 1·00 to 0·70.

(*b*) Take-off weight 66,400 lb. (This is not the sector weight requested by the operator, but is the maximum weight permitted by the weight, altitude and temperature (W.A.T.) limitation given in the flight manual.

(*c*) Ambient air temperature 32°C (ISA+28°C) which is the maximum value obtained from Fig. 3.

(*d*) A runway slope of minus one per cent.

*V_1 is the critical engine failure speed and V_2 the take-off safety speed.

The full lines are for no wind conditions and broken lines for a tailwind of 10 m.p.h.

From the plot it is clear that for the no wind case, the useful V_1/V_2 ratios lie between 0·890 where the system contains only runway and clearway and 0·825 where the system only contains runway and stopway. Between these two the system will contain runway, stopway and clearway in varying ratios.

It is interesting to note that between these two limit ratios the difference in the take-off distance required is only 350 ft. and the maximum distance required for Windhoek is 8,150 ft.

It has been found that the cost of construction of runways varies from 30s. to 40s. per sq. yd. depending on the nature of the soil. The cost of constructing stopways on dry stony areas such as exist at Windhoek is from 3s. to 4s. per sq. yd. while in most clay areas such as are found at George these costs range from 8s. to 10s. per sq. yd. In general the cost of clearways approximates to 2s. per sq. yd.

The two extreme cases of V_1/V_2=0·890 and V_1/V_2= 0·825 are considered in Table I which gives the cost per yd. width of strip from the end of the existing runway to the end of the take-off distance required. This method of assessment has been used purely as a means of comparing costs.

TABLE I

V_1/V_2 ratio	*Runway extension required*	*Stopway required*	*Clearway required*	*Estimated total cost of yd. wide strip*
0·890	Nil	1,600 ft.	Nil	£320
0·825	380 ft.	Nil	1,520 ft.	£622

From a study of the physical conditions and surveys made at Windhoek, it is possible to extend the existing runway at its southern end and to construct a stopway of 1,000 ft. length at the northern end.

Fitting these lengths into Fig. 4 a ratio of V_1/V_2= 0·870 is obtained and the required clearway, extension of runway and estimated cost are shown in Table II.

From Tables I and II, it is clear that the V_1/V_2 ratio of 0·890 which gives a balanced field length is the most economical and that the nearer the case is to the balanced field length, the more economical it becomes.

The runway system finally recommended for Windhoek Airport, based on the tailwind case with take-offs limited to the northerly direction only is given in Fig. 6.

TABLE II

V_1/V_2 ratio	*Runway extension*	*Stopway required*	*Clearway required*	*Estimated cost*
0·870	150 ft.	1,000 ft.	300 ft.	£455

The Jet Aircraft Problem

As large turbo-jet aircraft have already been ordered by South African Airways, and will also be placed into service by other operators, the existing aerodrome facilities will again need to be reviewed.

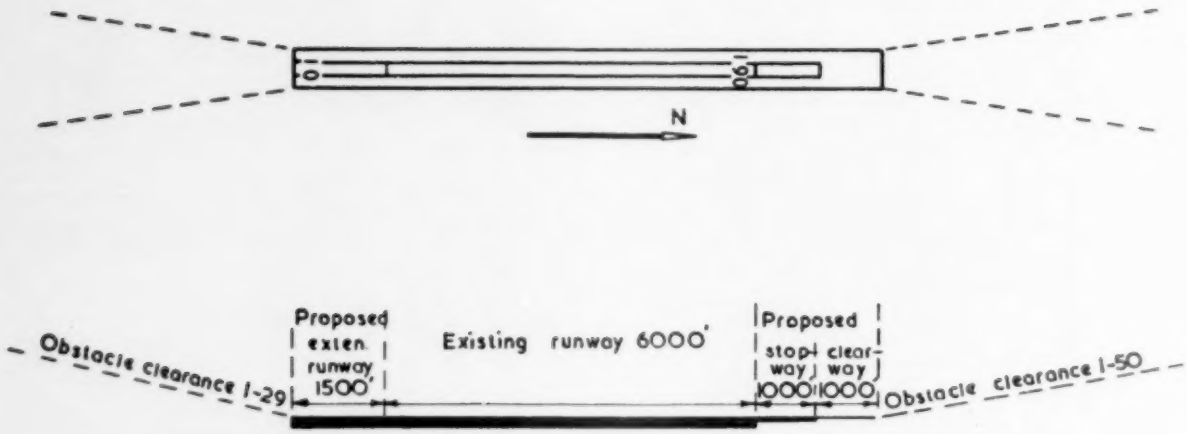


FIGURE 6. Proposed alteration of Windhoek Airport for Viscount 810 operation (not to scale).

The authorities are in a very difficult position because the aircraft manufacturer is not prepared to commit himself to firm performance figures before he has tested his product fully. This means that the performance information only becomes available at the time the aeroplane comes into service when suitable runway systems should already be available.

The planning of runway systems therefore must be made on estimated or approximate figures but, as the cost of runway construction is high, the authorities responsible for building them should not be expected to make them any larger than is absolutely necessary.

The operators do not usually pay for the construction or runways but they can and do ask for runway systems which will cater for the most critical conditions which are likely to occur in their operations. It again becomes a matter of compromise between the authorities and the operators coupled, of course, with the availability of funds.

Aeroplanes are getting bigger and better, but despite reductions in the operations margins they require more and more land for taking off and landing. The provision of suitable airports has therefore become one of the major problems in many States including South Africa.

On the Aerodynamic Design of Slender Wings

by

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SUMMARY:—Since flow separation occurs readily from a highly swept leading edge, but gives rise in general to a steady flow, it is proposed that the rational approach to the aerodynamic design of slender wings is to attempt to control, rather than to suppress, these separations. This leads to the suggestion that the leading edges should be sharp, and that the wing should be shaped so as to make them attachment lines at one attitude (the design attitude) at which classical wing theory can be applied. It is argued, further, that if the leading edge separations are to develop regularly with change of attitude of the wing, separation must occur only from the trailing edge at the design attitude; and the velocity field favourable to boundary layer development without separation forward of the trailing edge is discussed. Subject to the restrictions thus imposed on the design, low drag is sought at the design attitude. This leads to the consideration of a particular class of doubly curved mean surfaces satisfying the leading edge condition, onto which thickness distributions are superposed so as to provide favourable velocity fields together with low drag. A number of examples are considered, using slender thin wing theory for flexibility, to illustrate the manner in which plan form and thickness distributions affect the pressure distribution, and to indicate the relatively high lift/drag ratios which seem feasible. Some consideration is given to the limitations of the theory used and to the further developments which seem desirable.

1. Introduction

Experiment shows the flow pattern associated with a slender pointed wing to be largely dominated by leading edge separations*. For example, in the case of a symmetrical wing of this class, separation from a leading edge, even when rounded, appears to begin at the tip at zero lift, and to spread forward with increasing incidence until, still at a moderate lift coefficient, it occurs along the entire edge; variations in the shape of the edge seem only to affect the rate at which this spread takes place; and until the separations are fully established, they are likely to lead to irregular development of the flow pattern, with corresponding irregularities in the force and moment characteristics of the wing. Assuming, therefore, that separation of flow from the leading edges cannot be completely suppressed, it seems worth while to consider how its development may be controlled: if, for example, it can be fully established along the leading edges in all flight conditions, the development of the flow pattern with change in attitude of the wing will be determined primarily by the variation in the rate at which vorticity is shed from the edges, and will no longer be influenced by the uncontrolled spread of the separations; the flow pattern may then be expected to retain essentially the same form over a wide range of flight conditions, within which its development is likely to be regular. A necessary condition for the establishment of this flow is evidently satisfied by wings with sharp edges.

It is proposed, therefore, to consider the aerodynamic design of slender pointed wings with sharp edges, under the condition that flow separation from these edges shall dominate the flow pattern in all flight attitudes. This may appear to be very much at variance with the orthodox approach to wing design—in which separation, other than from the trailing edge, is taken to be undesirable—but the aim in each case is to establish a flow pattern which is characterised by open streamlines everywhere, and which can be maintained unchanged in form throughout the usable flight range; this objective can usually be achieved only if forward separation is suppressed, because we are usually concerned with flows which are essentially two-dimensional in character, so that forward separation necessarily gives rise to a separation bubble (assuming that the flow can be said to remain steady); but in the present case leading edge separation gives rise to a free vortex layer† precisely the same, in structure, as the trailing vortex layer originating from the trailing edge of any wing of finite span, and there is no evidence to suggest that a separation bubble (which is characterised by closed mean flow streamlines and appears to be a feature of an essentially unsteady flow) need be formed until well beyond the usable flight range of the slender wing. The present approach may therefore be regarded as a logical extension of accepted practice; it merely allows the trailing vortex sheet to originate from all the edges of the wing instead of only from the trailing edge.

The choice of sharp edges is the first restriction on the design but is not, in itself, sufficient for the establishment of the required flow pattern; it ensures separation from all edges—except, possibly, at one attitude—but

*Separation is taken here, and throughout this paper, to describe the departure from a solid surface of a thin layer of vorticity, which then makes its appearance in the interior of the fluid; separation in this general sense therefore occurs at, for example, the sharp trailing edge of a two-dimensional aerofoil, and is evidently bound to occur somewhere on any body of finite size[1].

Received 24th March 1959.

†Experimental evidence suggests that this type of flow invariably results from highly swept lines of separation.

it does not follow that these separations will be the primary or dominant ones. The addition of rudimentary sharp-edged wings to an axisymmetric body, for example, would not be expected to influence the flow pattern significantly; separation from the edges of the wings would occur, of course, but would be of sufficient strength to make only a local adjustment in the flow pattern; the primary separations would still be those occurring from the body itself and these, being uncontrolled, would violate our design conditions. It seems clear, from this example, that it is the complete shape of the lifting body, and not the edge alone, which determines whether the separation will be a primary one; and it is not likely to be possible for us to define a critical value of the cross-sectional edge angle below which primary separation is assured. This introduces a very real difficulty which cannot yet be resolved theoretically; and we shall consequently be forced to rely upon experiment to indicate whether a given wing will meet our requirements. There seems no reason, however, to expect a severe restriction upon the edge angle, provided that the wing is not too thick; and no reason why weak separations inboard of the edges should not be accepted.

Our design flow pattern is such that a good approximation should be provided by a potential flow in which a trailing vortex sheet originates from all edges of the wing. Notable contributions to the solution of this problem have been made by Legendre[2], Brown and Michael[3], Mangler and Smith[4, 5] and Küchemann[6]; but no approximate solution is yet available with the accuracy, and flexibility, required for design purposes. However, this does not altogether preclude the application of theoretical methods to the design of such wings. Our design restrictions have been concerned, so far, with the aerodynamic properties of a wing throughout its usable flight range; and these conditions can be met by any plan form consistent with the formation of free vortex layers from the leading edges, and by any cross-sectional shape and thickness distribution consistent with the regular development of the vortex layers as primary elements in the flow pattern. Subject to the restrictions thus imposed, the shape of the wing may be determined by properties required at one chosen attitude.

2. The Design Attitude

2.1. DEFINITION

For regular development of the flow pattern it is necessary not only that the leading edges should be sharp, but also that there should be one attitude at which the separations from them vanish altogether; at this particular attitude they become attachment lines, and the trailing vortex sheet originates wholly from the trailing edge, as it does in classical aerofoil theory. We choose this attitude as our "design point" primarily because its existence is essential to the existence of our prescribed flow pattern*; it defines, in effect, a class of mean surfaces—doubly-curved, in general, but containing the conically cambered delta plan form as a special case—upon which our designs must be based. Having defined this family of mean surfaces, the remaining properties of the wing ought, ideally, to be considered at any arbitrarily chosen attitude; but since this is impracticable, at present, it seems natural to take advantage of the convenient property which allows us to make use of conventional calculation methods at the "design point", and to determine the complete shape of a wing according to aerodynamic properties prescribed there.

It should not be supposed, however, that this procedure amounts to a reversion to the orthodox design approach. It simply follows, from our fundamental design principles, that there must always be one attitude, and only one, at which conventional methods of calculation are valid; and it may be expected that good aerodynamic design at this attitude will be reflected in the general properties of the wing. It does not follow that a wing of this kind would be expected to cruise at its design attitude; this can be settled only by experiment.

2.2. RESTRICTIONS

The design restrictions so far imposed are intended to favour the establishment of a flow pattern which is both aerodynamically acceptable (in theory) and physically attainable; to be consistent, therefore, we must also ensure that any flow pattern implied in a calculation at the design point can also exist in a real fluid. This amounts to the requirement that the pressure distribution shall be compatible with the existence of a boundary layer which may separate from the surface forward of the trailing edge only if the effect on the flow pattern is insignificant.

The required restrictions upon the pressure distribution are not yet fully understood, however, and we are obliged to proceed somewhat tentatively at this stage. There are two courses open to us: we may either attempt to establish, from theoretical reasoning, sufficient conditions for the existence of the design pressure distribution, and so restrict the design procedure rather more than may be necessary; or, bearing in mind the likely form of the restrictions, we may select designs with sufficiently varied nominal† pressure distributions and rely upon experiment to settle the existence problem. We may expect to design a wing which meets our basic requirements more readily if we follow the former course; but we shall not fully appreciate the potentialities of the slender wing until the necessary restrictions upon its design have been established experimentally. Since these two lines of investigation are evidently complementary, we propose to follow them both in parallel; and, in the process, to examine how variations in some of the geometric parameters defining the wing shape affect the nominal pressure distribution.

*It ensures that a leading edge vortex layer will always lie wholly on one side of an edge.

†*i.e.* according to a potential flow theory.

2.3. THE FAVOURABLE PRESSURE DISTRIBUTION

The required flow pattern will necessarily exist if the corresponding pressure distribution over the wing is everywhere favourable to boundary layer development without separation from the curved surface (*i.e.* such that separation can occur only at an edge). In a two-dimensional flow this pressure distribution is, of course, well known: separation from the curved surface can occur only in an adverse pressure gradient (that is to say, when the pressure increases in the streamwise direction). But the analogous conditions in a three-dimensional flow are more difficult to establish; the problem is complicated now by the existence of ordinary separation, or separation from a line along which the skin friction is non-zero; and it is with this form of separation that we are mostly concerned in practice, since the singular behaviour, with which we are familiar in two-dimensional flow, appears to occur only at isolated points, and free vortex layers plainly originate from lines.

We take ordinary separation to be described by a slightly modified form of the criterion given by Maskell[1]: this criterion defined the ordinary separation line as a cusp locus of the limiting streamlines on the solid surface; but later work (as yet unpublished) has shown that, although this condition describes the surface flow pattern in the neighbourhood of the separation line closely—especially for the present purpose—it must be relaxed somewhat, in order to permit the limiting streamlines to approach the line more or less asymptotically, rather than actually to meet it*. The distinction is of little concern to us here, however, since we require a qualitative description of the phenomenon rather than a criterion for it.

In the present context, the occurrence of ordinary separation is readily illustrated: consider, for example, the delta wing of Fig. 1, with nominal velocity distributions over its upper surface which lead to the streamline patterns shown by the solid lines; every point of the surface is traversed by a streamline of this family, every member of which may be said to originate from a leading edge; and if this is also true of the family of limiting streamlines in the real flow, the flow pattern can evidently exist. Now in the exact inviscid flow the surface streamlines are tangent to the leading edges and are initially concave inwards. Taking this to be the streamline pattern at the outer edge of the boundary layer in the viscous flow, the corresponding limiting streamlines (or skin-friction lines) on the surface will also be tangent to the leading edges and initially concave inwards; but the skin friction at any point of the surface would be expected to possess a component directed towards the centre of curvature of the streamline at the outer edge of the boundary layer.

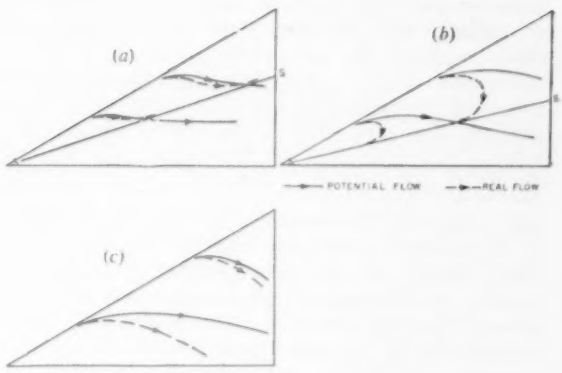


FIGURE 1. Possible surface flow patterns.

This may lead to failure of the limiting stream pattern to traverse the whole surface; and if it does, the lines bounding the region traversed by the pattern are lines of ordinary separation: the phenomenon is illustrated in Fig. 1, where the broken lines are the limiting streamlines, and the lines *SS* the lines of separation.

Figure 1(*a*) illustrates what appears to be the most likely form for the separation to take on a slender wing. A necessary feature of this pattern is an outward deflection of the limiting streamlines relative to the potential flow at the edge of the boundary layer; a line of separation of this kind cannot occur, therefore, until after the curvature of the external streamlines has changed sign; it could not exist if the potential flow streamlines were concave inwards everywhere. But we must still consider the possibility of separation occurring according to the pattern shown in Fig. 1(*b*). It is clear that this pattern requires the skin friction component in the direction of the external streamlines to change sign before the line of separation is reached; and, as in two-dimensional flow, the necessary change of sign could occur only where the pressure gradient following the external streamlines is positive.

These considerations suggest that a velocity field will be favourable to the required boundary layer development if it is such that the streamlines at the outer edge of the boundary layer are concave inwards, and the pressure is non-increasing along them. It is easy to show that if these conditions are satisfied separation, as defined here, is wholly excluded†.

However for the kind of flow considered here, where the potential flow streamlines show very little deviation

*It may be shown that the conditions near the ordinary separation line differ only in degree, and not in kind, from the conditions near any other surface streamline; but the line can still be distinguished, and a more precise definition of it can now be established. For the present purpose, however, the qualitative description given appears to be perfectly adequate, at least at this stage of the investigation.

†If separation were to occur in a favourable velocity field it could do so only along a line which is initially tangent to the leading edge, which could only be one of the limiting streamlines originating from the leading edge. But this would not prevent the limiting stream pattern from traversing the entire surface, and would therefore not amount to separation in the present sense. This cannot be taken to imply, however, that separation, in a more general sense, could not occur along such a line; but the consequent breakdown of the boundary layer approximations would have to occur in a somewhat different manner. Such a possibility may seem unlikely, but may have to be borne in mind.

from the undisturbed stream direction, it is convenient to replace these precise conditions by approximate ones, requiring the streamwise perturbation velocity component to be a non-decreasing function of the streamwise co-ordinate x, and the gradient dy/dx of the potential flow streamlines at the edge of the boundary layer to be a non-increasing function of x (*i.e.* requiring $\partial p/\partial x \geqslant 0$ and $(\partial p/\partial y)_{y>0} \leqslant 0$). The resulting surface flow pattern is illustrated in Fig. 1(*c*), from which it is clear that the boundary layer development on the centre section of the wing presents a difficulty; it appears, in fact, that separation might occur from that section although it seems unlikely that this would seriously modify the flow. It should be noticed, however, that we have not shown that our conditions will prevent every possible form of separation from the wing surface other than from the trailing edge.

It might be objected, at this point, that we have wholly ignored the possible occurrence of shockwaves which might also render the nominal flow pattern unrealistic; but they could occur only where the external flow requires a compression; and it follows that the pressure distribution which is favourable to boundary layer development, in the above sense, is also favourable to the development of a shock-free flow over the corresponding region of the wing surface.

3. The Potential Flow Problem

The design problem has been reduced, at this stage, to the solution of a much simpler potential flow problem at the design attitude; and we have proposed conditions which seem likely to determine the relevance of such a solution to the flow of a real fluid; but predictable aerodynamic characteristics at the design point, together with the reasonable certainty of their regular development with change of attitude, are not in themselves sufficient: the practical usefulness of a given wing will also depend upon the cruise performance of which it is capable, in particular upon the value of the lift/drag ratio attained at this attitude. It follows, according to the argument of Section 2.1.*, that a sufficiently low drag will be required at the design attitude, and we shall, therefore, approach our potential flow problem with this in mind. The examples that will be considered will be chosen for two purposes: to throw light upon the geometric and aerodynamic properties (especially the drag) of wings designed to possess favourable velocity distributions everywhere and, in the process, to demonstrate the existence of such wings; and to suggest an experimental programme which might be expected to provide data to check the validity of the basic assumptions, to indicate the extent to which unfavourable velocity distributions might be permissible in practice†, and to show how low a drag might ultimately be achieved without violation of the essential restrictions imposed upon the design.

We now have a well-defined potential flow problem to solve, but there is one further difficulty to which reference should be made before considering some specific examples. The difficulty in question is a purely mathematical one, arising from our inability to soive the exact problem; we are obliged, in fact, to approximate both to the exact potential equation and to the boundary conditions; and the uncertainty thus introduced into the calculations ought ideally to be fully examined. This has not yet been done completely, however; and although we shall attempt to justify our approximations in certain cases, some degree of uncertainty will necessarily remain in this preliminary investigation.

In the design studies which follow we shall be concerned only with supersonic main streams‡, where the total drag will include an important wave-drag contribution in addition to the skin friction and vortex drags; it will be assumed, in each case, that the wing is so slender that it lies well within the Mach cone from the apex, and so thin that the bow shock wave is attached and is followed by wholly supersonic flow; but, as we shall otherwise wish to consider a wide variety of wing shapes, we shall also accept as many additional approximations as are required for this purpose. For example, when calculating the velocity field we shall rely, for the most part, upon slender thin wing theory, because it provides the simplest, and therefore the most flexible, calculation method available; in this case, however, we shall be able to investigate some of the limitations of the method by comparison with more exact calculations.

Three main theories will be used in the course of the investigation, all of them based upon the small perturbation approximation and the linearised potential equation (therefore excluding transonic and hypersonic flows), but differing in respect of their additional assumptions. We shall refer to them as thin wing, slender body, and slender thin wing (or, simply, slender wing), theories; the first using the so-called thin wing approximation, the second the so-called slenderness approximation, and the third using both. In the thin wing approximation the boundary condition at the wing surface is satisfied in a plane, where the surface velocity distribution is also calculated; it implies that, for each transverse section of the wing, the maximum deviation from the plane in question is small, and the minimum radius of curvature large, compared with the local span. The slenderness assumption is concerned, on the other hand, only with the potential equation; the wing is assumed, in this case, to be so slender that the term $\beta^2\phi_{xx}$ (where $\beta^2 = M_0^2 - 1$ and M_0 is the free stream Mach number) is negligibly small compared with ϕ_{yy} and ϕ_{zz}; but in slender body theory the perturbation velocities are determined at the body surface.

The advantage of thin wing theories is that they permit independent solutions of the potential equation

*It was pointed out in Section 2.1 that there is no reason to suppose that the design and cruise attitudes need be identical but that, since the properties of the wing at any one attitude are likely to be related to its general properties, we may confine our calculations to the design point.

†Boundary layer calculations will also be helpful for this purpose, but will not be considered in this paper.

‡The slender wing is likely to be considered, in practice, only for aircraft with supersonic cruising speeds.

to be added in the following sense: we may separately consider thickness distributions in relation to symmetrical wings at zero lift, and thin doubly-curved lifting surfaces at the design attitude, and finally add the two velocity distributions to obtain the flow field of a thick cambered* wing. Moreover, if we accept the first approximation to the pressure ($C_p = -2u$, with unit free stream velocity), the calculated drags thus determined are also directly additive (no interference terms occur). To this approximation, however, there is no wave drag due to lift in slender wing theory and, to rectify this, we shall take the load distribution given by slender-wing theory and calculate the corresponding wave drag according to the so-called not-so-slender-wing theory of Adams and Sears[7]; this would be related, strictly, to a somewhat different wing, but might be expected to serve as a reasonable first approximation, provided that it is not too large.

It should be noticed that the small perturbation approximation may be expected to be valid even at the leading edges of a slender wing, because of their high sweep; but, unless the edges are also cusped, the boundary conditions cannot, strictly, be linearised there; if they are the calculated velocity becomes logarithmically infinite. It can be shown, however, that the zero lift drag of a symmetrical slender wing, with sharp leading edges and an unswept trailing edge, is the same whether it is calculated according to slender wing or slender body theory (using the Ward-Lighthill formula[8, 9])† so that, in this respect at least, the logarithmic infinity is not a serious failing; but a more realistic estimate of the velocity field, as would be given by slender body theory, would be preferred for boundary layer calculations. Apart from this, the thin wing approximation evidently requires sufficiently small thickness and camber to be valid in practice, and we have not yet shown that it is fully justified for the wings we shall consider. Nor have we yet shown that the slenderness assumption is always justified; it seems possible that it may sometimes break down, with the cambered surfaces considered, because of high local values of $\beta^2\phi_{xx}$, even though the usual slenderness parameter $\beta s/c_0$ may be small.

4 Some Particular Examples

Some particular examples will now be considered, restricted, in the present investigation, to wings with unswept trailing edges. The calculations are then relatively easy to perform; and we are able to examine the effects of the design restrictions, which are concerned essentially with conditions forward of the trailing edge, more or less in isolation. This configuration may not be the most desirable one in practice, however, and it is clear that the influence of trailing edge angle of sweep on the attainable aerodynamic properties of a wing will have to be investigated in due course.

4.1. SYMMETRICAL WINGS AT ZERO LIFT

Some uncambered wings will be considered first at zero lift (their design attitude), both for their own sake and for later use in the construction of a thick cambered wing; and, since our aim is to design wings for which the flow conditions vary smoothly with attitude of the wing, we require the slopes of streamwise sections to be continuous; we therefore exclude the double-wedge sections mostly considerd by others (*see*, for example, Puckett[11] and Henderson[12]), but more because we are unable to predict the importance of the separations necessarily occurring at the ridge lines than because we believe that they would always lead to undesirable aerodynamic properties (this, again, is a matter for experiment).

To compare the thin wing and slender thin wing theories, we choose wings with particularly simple geometric properties for a few of our examples[13]; these are of delta plan form and have rhombic transverse sections.*

The first example, wing I, has biconvex chordwise sections, with a thickness/chord ratio which decreases linearly along the span. The streamwise perturbation velocity u and the slope dy/dx of the streamlines (for a free stream Mach number $M_0 = 1{\cdot}56$) have been calculated according to slender thin wing theory; and since the streamlines deviate little from the free stream direction we plot u and dy/dx for $y =$ constant in Fig. 2, where it appears that u increases with x, while dy/dx decreases, over the entire wing surface. In this case, therefore, the velocity distribution is everywhere favourable to boundary layer development, in the sense of Section 2.3. The displacement thickness of this boundary layer may be expected to modify the effective contour of the wing so as to lead to a slight reduction of the suction over the rearward facing surfaces; and at, or near, the trailing edge an oblique shock would occur, but one which would not be expected greatly to affect the flow upstream of it. It seems likely, therefore, that the calculated flow pattern is a good approximation to the actual flow over the wing, and that a wing exists with the required favourable pressure distribution everywhere over its surface.

Wing II is also a delta wing of the same aspect ratio A and volume V as wing I, and also has rhombic cross sections, but its chordwise sections are such that its cross-sectional area distribution is the same as that of a parabolic body of revolution†, and the trailing edge

*We shall use camber to describe a doubly-curved mean surface, and not to imply only curvature in streamwise sections.

†This agreement results from the fact that the leading edge singularity which occurs with a round nosed section, and contributes to the drag (*see* Ref. 10), does not exist for wings with sharp leading edges.

*The ridge line on the centre section, at which separation would occur when the wing is yawed, might be an undesirable feature in practice; but the use of cross-sectional shapes which are not rhombic, and which vary along the chord, involves unduly lengthy calculations with thin wing theory, though not with slender wing theory. For the purposes of comparison, it appears to be sufficient to consider only the simpler shapes.

†This area distribution leads to very nearly the minimum attainable wave drag for a body of revolution, though not, as will be shown, for a wing.

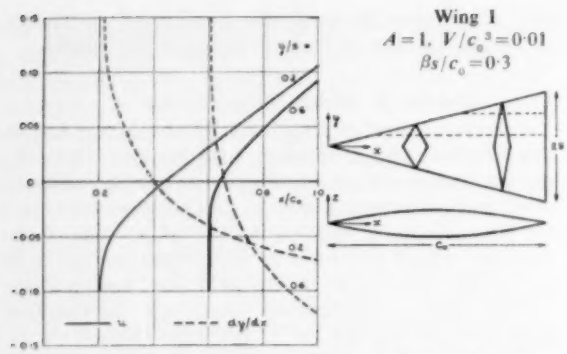


FIGURE 2. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$ by slender wing theory.

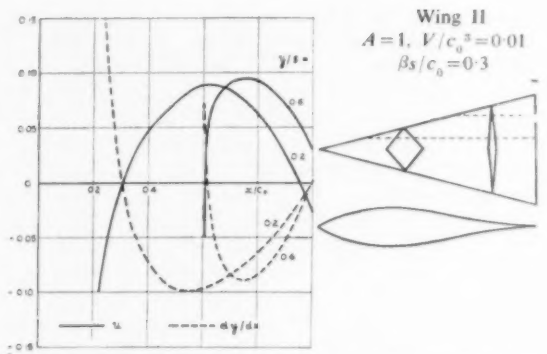
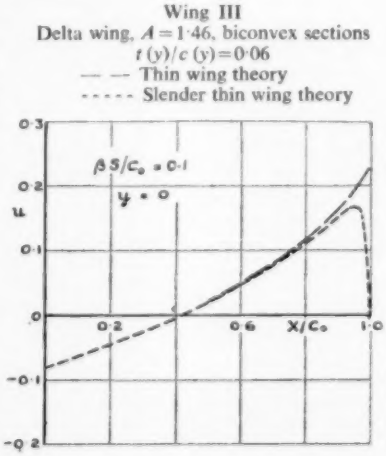


FIGURE 3. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$ by slender wing theory.

is therefore cusped over the entire span. The theoretical results, plotted in Fig. 3, show that an unfavourable velocity distribution is predicted over much of the wing surface; the manner in which the slope of the streamlines varies along the chord implies unfavourable curvature, with the risk of separation occurring forward of the trailing edge; and, as a consequence of this, or of the possible occurrence of a shockwave where the adverse pressure gradients are predicted, the calculated pressure distribution might not be realised in practice. Wing II is therefore an example of a wing which violates the sufficient conditions that have been imposed upon the pressure distribution; but it might be a suitable subject for an experiment intended to clarify the extent to which those conditions are necessary.

Experimental evidence against which the validity of these arguments could be checked is limited, as yet; we know of only one measured pressure distribution on a sharp-edged delta wing with smooth streamwise sections; this was obtained by Drougge and Larson[14] for a wing with biconvex chordwise sections of constant thickness/chord ratio. The calculated perturbation velocity at the centre section of this wing, according to both the thin wing and slender wing theories, is plotted in Fig. 4, together with the observed distribution*. Thin wing theory agrees fairly well with experiment, in this case, especially over the front part of the wing; the differences over the rear part are such as might be expected to result from the thickening of the boundary layer in the chordwise direction, together with a possible upstream influence of the trailing edge shock wave.



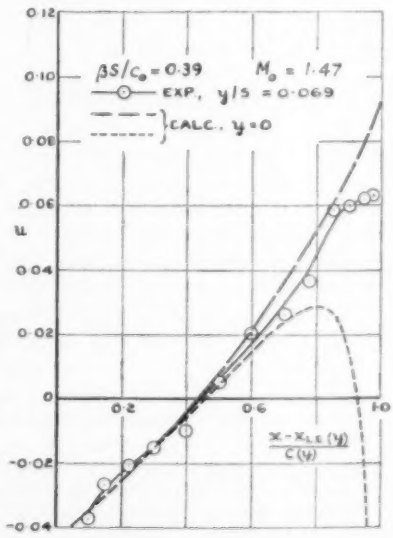


FIGURE 4. Velocity increments at the centre.

The failure of slender wing theory near the trailing edge of wing III, also shown in Fig. 4, is a consequence of the fact that the slenderness assumption is no longer valid there. The second chordwise derivative of the cross-sectional area distribution of this wing is infinite at the trailing edge; this leads to a logarithmically infinite perturbation velocity there; and the region over which the velocities differ noticeably from those given by thin wing theory increases in extent with the slenderness parameter $\beta s/c_0$ (*see* Fig. 4).

This difficulty does not arise with wings I and II, however, because the second derivatives of their area distributions, and the corresponding perturbation velocities, are finite at their trailing edges (*see* Figs. 2 and 3). A comparison between the thin wing and slender wing theories may usefully be made, therefore, with these wings, and the corresponding velocity distributions are accordingly plotted in Figs. 5 and 6, for a free stream Mach number $M_0=2$ (*i.e.* for $\beta s/c_0=0{\cdot}43$). In view of the fair agreement between the two sets of results, it seems reasonable to conclude that slender wing theory predicts the characteristic features of the theoretical

*The comparison is made only for the centre section because the complete velocity field according to thin wing theory has not yet been calculated.

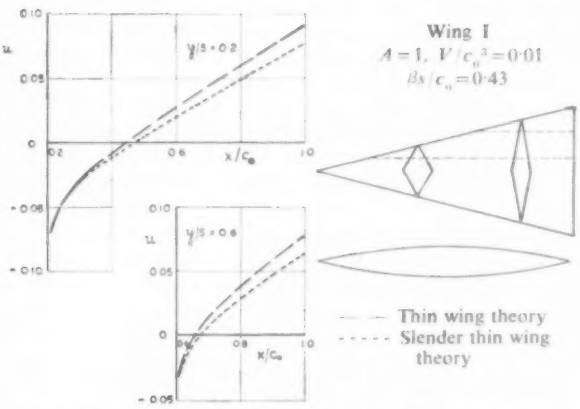


FIGURE 5. Velocity distributions by two methods at $M_0=2$.

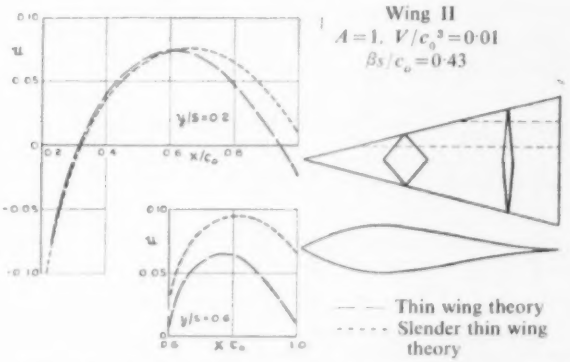


FIGURE 6. Velocity distributions by two methods at $M_0=2$.

pressure distribution on a delta wing in supersonic flow quite satisfactorily—with the possible exception of the trailing edge—even if the wing is not extremely slender; the examples suggest that the slenderness parameter $\beta s/c_0$ need only be less than about 0·4.

These results have some bearing on the validity of calculated wave drags, the reliability of which can evidently be assessed only when the theoretical pressure distributions are also known. It may be useful, therefore, to examine the calculated drags of wings I, II and III before considering any further examples; these are plotted in Fig. 7 against the free stream Mach number M_0. All the calculations are invalid for Mach numbers close to unity because the linearised potential equation is not then applicable (as $M_0 \longrightarrow 1$ the pressure coefficients tend to infinity), and experiments must define the minimum Mach number at which the use of this equation is justified. Apart from this, we would expect the calculated drag of wing I, on which no adverse pressure gradients occur, to be a reasonably accurate estimate of the actual wave drag—indeed, the boundary layer displacement effect, together with the upstream influence of the trailing edge shock, would be expected, if anything, to make it a slight overestimate—but for wing II, where there is some doubt about the existence of the assumed flow pattern, there must be a corresponding doubt about the reliability of the calculated drag*. It may be noticed, here, that the use of thin wing, rather than slender wing, theory to calculate the drags of these two wings, makes a difference, for $\beta s/c_0=0{\cdot}43$, of about 10 per cent in each case.

The pressure distribution on wing III has so far been calculated, by thin wing theory, only for the centre section, and no corresponding drag can yet be given. When calculated according to slender wing theory, the drag becomes implausible for the higher values of the slenderness parameter (*see* Fig. 7); but this is only to be expected, in view of the way in which the theory fails at the trailing edge in this case.

Our requirement of predictable aerodynamic properties is evidently satisfied by wing I at zero lift, but the high suction forces on the rearward facing surfaces of this wing suggest that a lower drag could be obtained, without violating that requirement, on a wing with reduced suction forces near the rear. Until there is experimental evidence to indicate the extent to which an adverse velocity field can be tolerated, a wholly favourable one—such as is very nearly obtained on wing IV—is to be preferred. This wing also has rhombic cross sections, in order to simplify the calculations, and its streamwise perturbation velocity and streamline slope are shown in Fig. 8. The wave drag of wing IV is compared with the drags of wings I and II in Fig. 9;

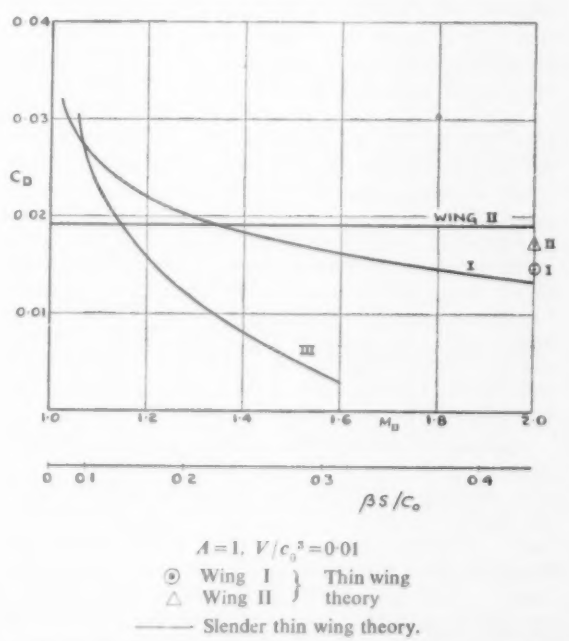


FIGURE 7. Wave drag coefficients for wings of equal volume.

*The parabolic body of revolution, which has the same area distribution as wing II, also has the same theoretical drag, but the adverse pressure gradients are much smaller on the body of revolution than on the wing, so that their drags may well differ in a viscous flow.

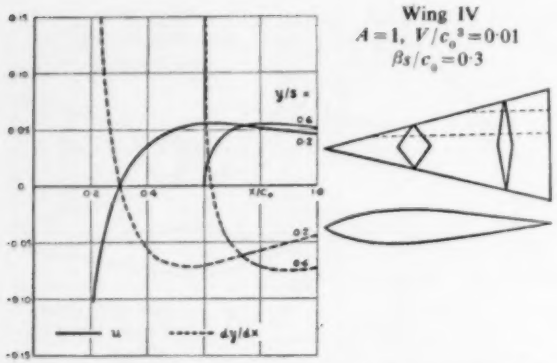


FIGURE 8. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$ by slender wing theory.

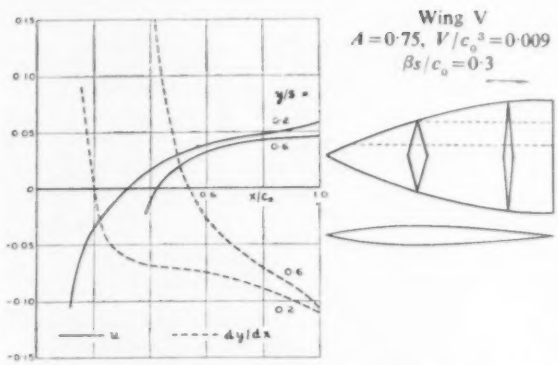


FIGURE 10. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$ by slender wing theory.

all three wings have the same plan form and volume*. The drag of wing IV is less than that of wing I for the whole Mach number range considered; it is also less than the drag of wing II, except for values of M_0 close to unity. This indicates that the body of revolution which is pointed at both ends, and which has the minimum wave drag according to the sonic area rule, does not provide the optimum area distribution for slender wings, with finite trailing edge span, at Mach numbers greater than unity; this is because the slender wings comprise a larger family of slender bodies than are included in the bodies of revolution, the first chordwise derivative of the area distribution no longer being restricted to zero at the trailing edge.

So far only delta wings with rhombic cross sections have been considered but, for a given cross-sectional area distribution, both the pressure distribution and drag can be modified, to some extent, by altering the shape of the plan form (*e.g.* from a delta wing to a wing with streamwise tips) or the shape of the cross sections (*e.g.* from rhombic to biconvex). In order to illustrate this Fig. 10 shows the chordwise velocity increments and the streamwise slopes of a wing V, which has a plan form with streamwise tips, rhombic cross sections, and the same area distribution as wing IV. Some further results are quoted in Ref. 15.

Since the ultimate aim is the design of a cambered wing with finite thickness, and since the double curvature of the mean surface will then affect the pressure distribution, there seems little point in seeking the thickness distribution which leads to the minimum zero lift wave drag at a given Mach number. At this stage of the investigation, low drag, rather than minimum drag, appears to be the more suitable objective.

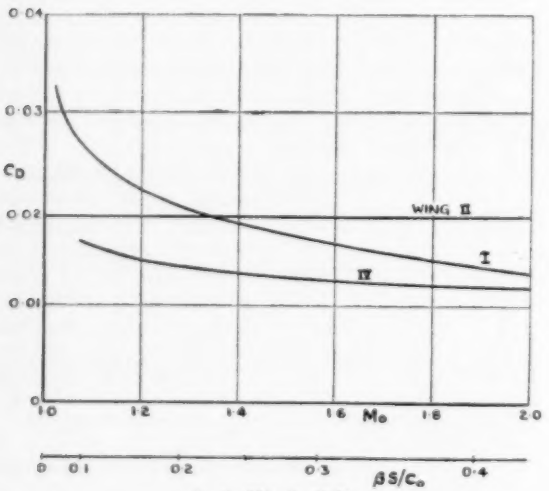


FIGURE 9. Wave drag coefficients for wings of equal volume by slender wing theory.

4.2. CAMBERED WINGS AT THE DESIGN ATTITUDE

Although symmetrical wings can clearly be designed to meet our requirements, the fact that their design attitude corresponds to zero lift is something of a disadvantage, theoretically, since we are unable to predict any of their properties in the lifting condition; experiment suggests, however, that at small values of the lift coefficient the lift-dependent drag of such wings is about twice the value it would have if attached flow round the leading edges could be achieved; this arises because little non-linear lift increment results from the presence of the leading edge vortex sheets under these conditions. It seems reasonable to suppose that a higher lift/drag ratio might be reached, at cruise, by a wing designed for a positive lift coefficient rather nearer to a suitable cruise value; cambered members of the general family of wings defined in this paper are of particular interest, therefore, and we conclude the present investigation with some further examples illustrating their design.

The subsonic leading edges are attachment lines when the local load along them is zero, a condition which can be fulfilled, at one attitude, by a large family of wings including, of course, symmetrical wings at zero lift. Our purpose is to design wings of this family which, at a given lift coefficient, have low lift dependent drag; and we seek, in effect, to obtain sufficient suction

*It might, of course, be better to keep different parameters constant in a given design study.

on forward-facing surfaces for the drag to be nearly as low as the minimum predicted for flat wings at incidence, with the unattainable attached flow round their leading edges. This implies that we must attempt to obtain a nearly elliptic spanwise distribution of chord load (to approach minimum vortex drag), and a nearly elliptic chordwise distribution of cross-load (to approach the lower bound of the wave drag given by R. T. Jones[16])*.

It is preferable, at this stage, to restrict the geometry of the wings as little as possible, and to use methods of calculation which are simple enough to allow large numbers of wings to be designed. Apart from the requirement that the plan form shall be pointed at the apex, with its span a non-decreasing function of streamwise distance, we therefore permit considerable generality in the wing shape—accepting, in particular, doubly-curved mean surfaces—and we continue to base our calculations upon slender wing theory, except to the extent that we make an estimate of the lift dependent wave drag, using the not-so-slender thin wing theory of Adams and Sears[7].

Before considering the general problem in more detail, it should be noticed that the special case of conical flow has been treated by Smith and Mangler[17], using the methods of thin wing theory. They have obtained wings with low drag by the superposition of a finite number of load distributions, each satisfying the condition of zero load at the leading edges; but, in conical flow, the drag is apparently close to that of a flat wing with attached flow round its leading edges, only when there are high suction peaks and adverse pressure gradients near the leading edges; moreover, the chordwise distribution of cross load differs somewhat from the optimum elliptic distribution desirable for slender wings. The results obtained in this special case† are of considerable interest, however; they provide, in particular, some indication of the limitations of the slender wing theory.

It seems useful, in this preliminary investigation (as in Ref. 19), to concentrate upon wings with transverse curvature confined to limited regions near their leading edges; but the approximation of such wing shapes, by the superposition of a finite number of basic load distributions, is likely to lead to some waviness, both in the wing shape itself, and in the corresponding pressure distribution. This can be avoided, however, if both wing shape and load distribution are partially prescribed; and in the present case, we prescribe the form of the spanwise distribution of downwash (within thin wing theory, the spanwise distribution of the chordwise slope $\partial z/\partial x$ of the wing), but allow the ratio of the downwash at the leading edge to its value in the plane of symmetry to remain arbitrary; it may then be chosen so as to satisfy the zero load condition at the leading edges. In some cases, we introduce a further condition, requiring the spanwise distribution of chord load to be elliptic at the trailing edge, in order to obtain minimum vortex drag; but the chordwise curvature of the centre section remains arbitrary, and can evidently be chosen so as to meet one further requirement: this might be taken, in practice, to be small wave drag or, perhaps, a given pitching moment.

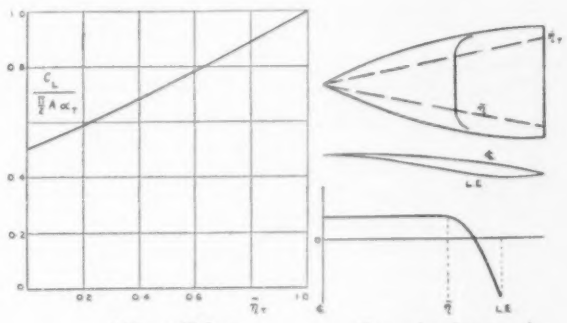


FIGURE 11. Lift coefficient and spanwise downwash distribution.

The spanwise distribution of downwash considered here is constant over the inner part of the wing, with quadratic variation over the outer part; and the spanwise position, $\bar{\eta}$, of the "shoulder", at which the transverse curvature begins, is a free parameter which can be taken to vary along the chord. The ratio of the downwash at the leading edge to its value at the centre section—chosen so as to make the load zero at the leading edge—increases with outward movement of the shoulder position.

According to the assumptions of slender wing theory, the total lift coefficient is fully determined by the downwash distribution at the trailing edge; it therefore depends, in the present case, solely upon the value of the parameter $\bar{\eta}_T$. This dependence is illustrated in Fig. 11, where the lift coefficient of the cambered wing is plotted as a fraction of its value for $\bar{\eta}_T=1$; a nearly linear decrease of the lift ratio results from an inward movement of the shoulder position $\bar{\eta}_T$. The vortex drag factor $C_{D_0}\pi A/C_L^2$ also depends only on the spanwise distribution of downwash at the trailing edge; and Fig. 12 shows that it increases nearly linearly from one to 4/3 as the shoulder position moves inward.

An estimate of the lift dependent wave drag can only be made if the slenderness assumption is dropped. For a given wing, the load distribution then varies with the free stream Mach number; and a cambered wing, designed according to slender wing theory (*i.e.* for small $\beta s/c_0$) to have zero load at its leading edges, consequently need not continue to satisfy that condition for larger values of the slenderness parameter; in fact, the load distribution given by slender wing theory could be

*The elliptic chordwise load distribution gives a lower bound to the wave drag only in the limit $\beta s/c_0 \to 0$. For non-zero $\beta s/c_0$, a somewhat lower theoretical minimum wave drag can be obtained with a non-zero load at the trailing edge.

It might be preferable to relax these conditions in practice, so that other requirements (of either an aerodynamic or geometric nature) might be satisfied; it might be desirable, for example, to prescribe the position of the centre of pressure to ensure a low trim drag.

†G. Roper[18] has obtained some solutions for delta wings with non-conical camber, again using thin wing theory.

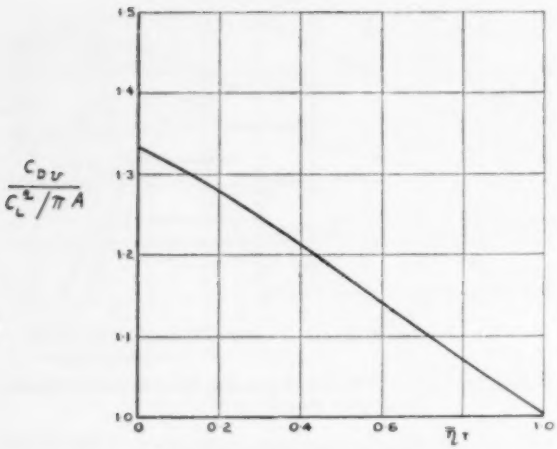


FIGURE 12. Vortex drag factor.

obtained at a non-zero value of $\beta s/c_0$ only with a somewhat different wing shape. The use of thin wing theory is necessary to determine this effect, which has not yet been calculated for a curved plan form; in conical flow, however, Smith and Mangler[17] find that with a given conical load distribution the variation of downwash, in the range $0 < \beta s/c_0 < 0{\cdot}5$, is both small and nearly constant over the wing surface, so that the required wing shape varies very little with Mach number in this case. In view of this result, we propose to estimate lift dependent wave drag at a non-zero value of $\beta s/c_0$, by taking the load distribution derived by slender wing theory (and relating, strictly, to a wing designed for $\beta s/c_0 = 0$) and thence deriving a wave drag by means of the not-so-slender wing theory of Adams and Sears[7]; we therefore propose to ignore the fact that this would apply, strictly, to a somewhat modified wing.

Some of the properties of doubly-curved mean surfaces of the family defined above, are illustrated in Figs. 13 to 15. These relate to two particular surfaces, the first of which (wing VI) is designed for minimum vortex drag (*i.e.* $\bar{\eta}_T = 1$). To avoid an infinite load at the tip in this case, it is necessary for the plan form to have streamwise tips, and for the shoulder lines to be tangent to them: the local load at the trailing edge is then zero with an uncambered centre line, and the velocity distribution is consequently unfavourable to the required boundary layer development over much of the upper surface. Moreover, since the perturbation velocities on the lower surface are of the same magnitude, but opposite sign, the velocity distribution there is also unfavourable in part, but now only near the leading edges; and, in the absence of experimental evidence, it is debatable whether this might lead to separation from the lower surface, or whether, if it did, the consequent modification to the flow pattern could be expected to be confined to the neighbourhood of the leading edges. However, perhaps a rather more important feature of this wing is the high curvature* of transverse sections near the trailing edge, which might well lead to separation near the shoulder under all flight conditions.

The velocity distribution can be improved somewhat if minimum vortex drag is not demanded; we can then allow $\bar{\eta}_T$ to be less than unity, as for wing VII, and obtain the kind of improvements illustrated in Fig. 14. The velocity distribution is still not wholly favourable in this case; it can be made so on the upper surface by suitably cambering the centre section but, apart from the wholly unfavourable distribution then obtained on the lower surface this also leads to a chordwise distribution of cross-load which is undesirable on two counts: it gives rise to a higher wave drag than that predicted for the uncambered centre section, and it usually places the centre of pressure in an impracticable position. The condition of zero load at the leading edges requires the corresponding spanwise velocity component also to be zero, so that the adverse velocity field near the leading edges on the lower surface can never be eliminated on thin wings of this class.

These two examples forcibly illustrate the importance of defining the extent to which an adverse velocity field can be tolerated; experimental evidence on this question is needed before further progress can be

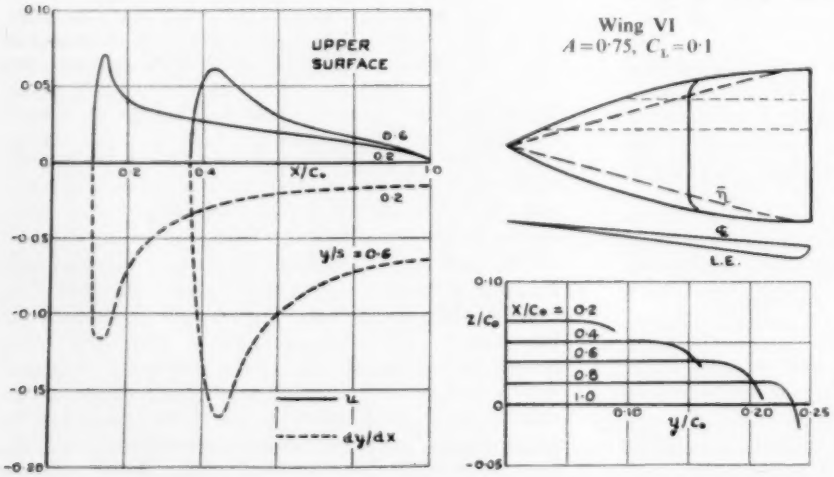


FIGURE 13. Chordwise velocity increment and streamline slope by slender wing theory.

*The validity of the thin wing approximation may be in doubt in this case; it may not be permissible, in fact, to represent the wing by a plane distribution of singularities, and to satisfy the boundary conditions in that plane. Moreover, the slenderness assumption (*i.e.* that $(M_0^2 - 1)\,\partial u/\partial x \ll \partial v/\partial y$) might also break down as a result of the locally high streamwise gradients of the streamwise velocity component.

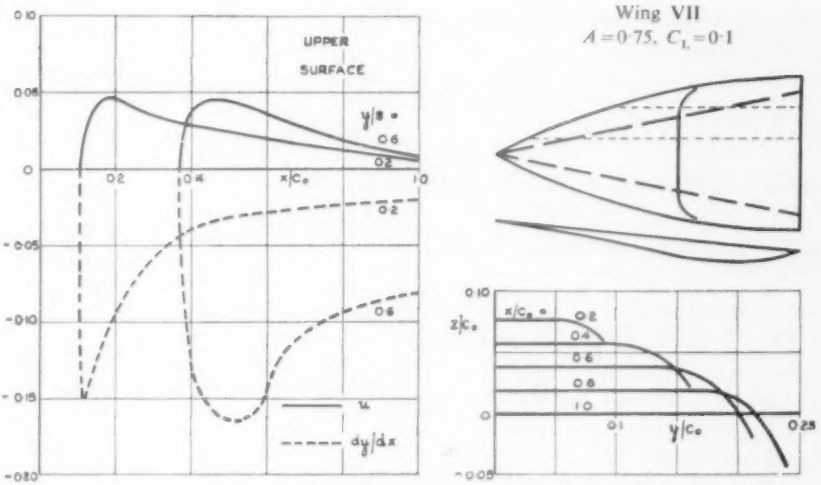


FIGURE 14. Chordwise velocity increment and streamline slope by slender wing theory.

made in the design of thin cambered wings*. But if uncertainties of this kind are ignored, the drags of wings VI and VII are readily estimated; they are plotted in Fig. 15, together with the drag of the plane wing of the same plan form, but under the assumption of attached flow round its leading edges; the figure also includes the lower bound† of the slender wing defined by R. T. Jones[16]. Although the vortex drag factor of the flat wing with leading edge separation decreases with increasing lift coefficient (because of the non-linear lift increment resulting from the leading edge vortex sheets), it is reasonable to assume that the drag of such a wing would greatly exceed the drag of either of the two cambered wings, at the given value of the design lift coefficient. Wings VI and VII must therefore be regarded as low drag designs, provided that their pressure distributions are attainable in a real flow; and, particularly in view of the latter uncertainty, there seems little point, at this stage, in attempting to design an optimum mean surface in respect only of the drag.

However, the difficulties arising in the design of thin cambered wings are rather less important than they may appear, because they can be greatly reduced by the addition of suitable thickness distributions. The result of combining velocity fields due to both thickness and camber is illustrated in Figs. 16 to 18 for the final example, wing VIII, which has the mean surface of wing VII and the thickness distribution of wing V. The adverse velocity gradients associated with the mean surface are so much reduced in this case, by the superposition of the velocity field due to thickness‡ that it seems reasonable to suppose that the required flow pattern might well be attained in practice.

5. Concluding Remarks

The restrictions which, in the light of present knowledge, are considered sufficient for the establishment of the required flow pattern at the design attitude, seem almost certainly too severe for this purpose alone; but they still may be insufficient to ensure a regular development of the flow pattern as the attitude of the wing is varied and this, after all, is the first principle on which the present approach is based. It can be argued, however, that a wholly favourable velocity field, in the sense of Section 2.3, would also be expected to favour the subsequent establishment of primary separations from the sharp leading edges; and if this were so, wings V and VIII would then be expected to satisfy all of the conditions imposed upon the design, having, in particular, reasonably low drags at their design attitudes, together with good aerodynamic properties in all other flight conditions. But this, like many of the underlying assumptions used in the development of these wings, still requires experimental confirmation;

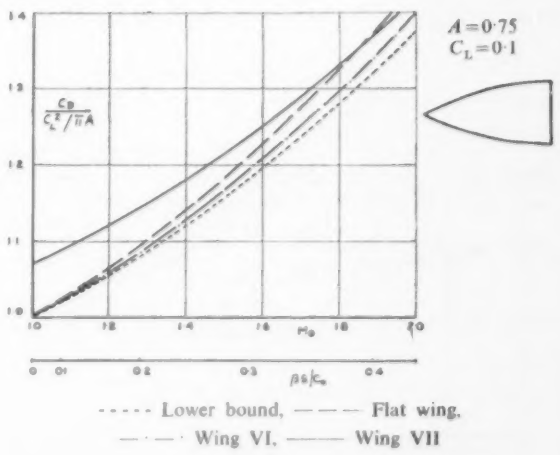


FIGURE 15. Lift dependent drag.

*Experiments are also needed to define the conditions which might legitimately be prescribed at the trailing edge. It is not yet clear how nearly a given finite load at the trailing edge can be realised in practice; and it seems quite possible that the complex system of compression and expansion waves, which occur near the trailing edge in a real flow, might so modify the pressure distribution as to lead to a significant reduction of lift at the design attitude.

†The optimum plan form which would achieve this lower bound in "attached flow" differs somewhat from the plan form ($s(x)=sx(2-x)$) of wings V-VIII.

‡The improvement in the velocity field near the leading edges on the lower surface is exaggerated here because the calculated velocity components due to thickness are logarithmically infinite at the leading edges (*see* Fig. 10), according to thin wing theory. In reality, the velocity component in a plane normal to a leading edge is zero at the edge.

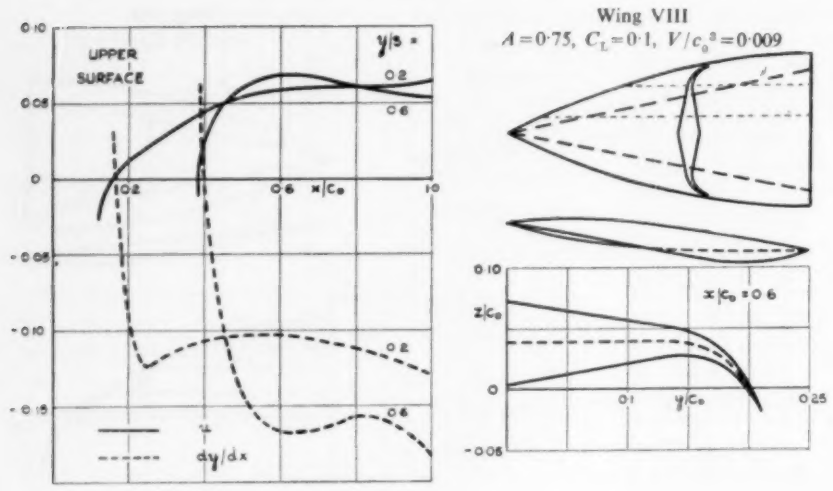
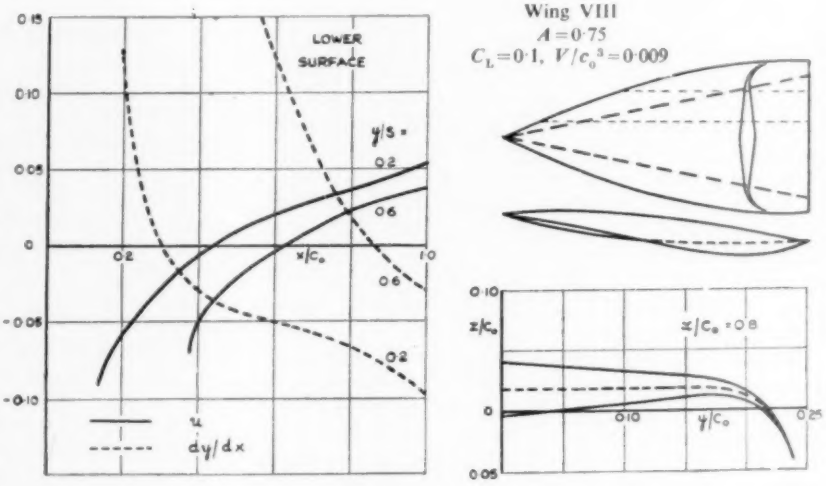


FIGURE 16. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$.

FIGURE 17. Chordwise velocity increment and streamline slope at $M_0=1{\cdot}56$.



and it should, perhaps, be emphasised that an important purpose of this investigation has been the development of a series of wings for wind tunnel experiments, with the object of clarifying the necessary design restrictions.

With these reservations in mind, and remembering also that no great effort has been made to minimise the total drag or to prescribe the position of the centre of pressure, the calculated properties of wing VIII at its design attitude appear to be reasonably promising. Its wave and vortex drags are given in Fig. 18; and with an estimated full scale skin friction drag coefficient of about 0·0025, the corresponding lift/drag ratio, at a Mach number $M_0=2$, amounts to about 6·3. However, this value varies greatly with the volume of the wing, a decrease of 20 per cent in volume, assumed to affect only the wave drag, increasing the estimated lift/drag ratio by 20 per cent to about 7·5.

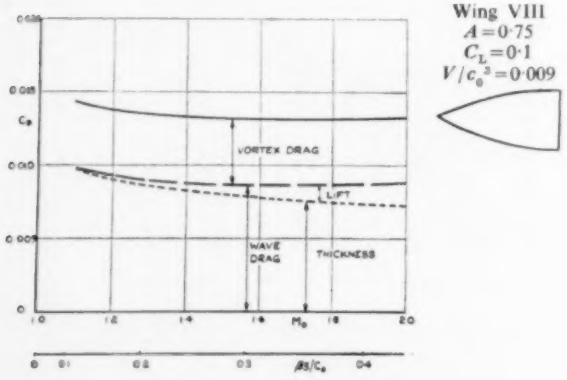


FIGURE 18. Drag coefficients.

The position of the centre of pressure of this wing is also of some interest: it lies at 52 per cent of the root chord at the design attitude, a position which has been measured at low speeds for an uncambered wing of the same type of plan form, but with an aspect ratio of one, in the interval $0{\cdot}2 < C_L < 1{\cdot}2$*. Such a coincidence of the centre of pressure, for the supersonic design point and for high lift at low speed, is difficult to achieve with a delta plan form required to possess a wholly favourable velocity field.

The characteristics of wing VIII have much to

*The thickness distribution of this wing was somewhat different from that used for wing VIII: it had a 12 per cent thick biconvex centre section, with rhombic transverse sections.

recommend them, therefore, and since its velocity field is such that the calculations would be expected to provide good first approximations to its properties in a real flow, it seems to be a particularly suitable subject for an experimental investigation, together with the corresponding uncambered wing.

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TECHNICAL NOTES

The Critical Height of Distributed Roughness to Cause Boundary Layer Transition

by

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IT HAS BEEN found[1, 2] that there is a critical height for "sandpaper" type roughness below which no measurable disturbances are introduced into a laminar boundary layer and above which transition is initiated at the roughness. Braslow and Knox[3] have proposed a method of predicting this height, for flow over a flat plate or a cone, using exact solutions of the laminar boundary layer equations combined with a correlation of experimental results in terms of a Reynolds number based on roughness height, k, and local conditions at the top of the elements. A simpler, yet more general, method can be constructed by taking additional advantage of the linearity of the velocity profile near the wall in a laminar boundary layer.

NOTATION

A, B, C	functions defined in equation (3)
C_p	specific heat of air
I	static enthalpy
k	maximum roughness height
R	critical Reynolds number based on conditions at height k in the boundary layer
r	recovery factor
T	static temperature
u	local velocity
y	distance normal to wall, from surface
μ	viscosity
ρ	density
τ	shear stress
ω	exponent in viscosity-temperature power law relationship

Suffixes

e	conditions at outer edge of boundary layer
k	evaluated at height k from the wall, within the boundary layer
r	"recovery" or adiabatic wall conditions
w	wall conditions

ANALYSIS

Near a wall in a laminar boundary layer

$$u \simeq \frac{\tau_w}{\mu_w} y \ .$$

The wall shear τ_w is obtained from the appropriate skin friction formula. The critical Reynolds number is given by

$$R = \frac{\rho_k u_k}{\mu_k} k = \frac{\rho_k}{\mu_k}\left(\frac{\tau_w}{\mu_w}\right) k^2 \ . \quad . \quad . \quad (1)$$

Local flow properties are related to wall conditions using a modified Crocco expression

$$\frac{I_k}{I_w} = 1 + \frac{I_r - I_w}{I_w}\left(\frac{k}{u_e}\frac{\tau_w}{\mu_w}\right) - \frac{r}{2I_w} k^2 \left(\frac{\tau_w}{\mu_w}\right)^2 \ . \quad (2)$$

where I is the static enthalpy and r the recovery factor. For a given value of R equations (1) and (2) can be solved for k using equation (2) to evaluate ρ_k, μ_k in equation (1).

In the particular cases for which it is sufficient to assume C_p=constant, and $\mu \simeq T^\omega$ then equations (1) and (2) become

$$1 + Ak - Bk^2 = (Ck^2)^{1/(1+\omega)} \ . \quad . \quad (3)$$

where $$A = \left(\frac{T_r - T_w}{T_w}\right)\frac{\tau_w}{u_e \mu_w}$$

$$B = \frac{r}{2C_p T_w}\left(\frac{\tau_w}{\mu_w}\right)^2$$

and $$C = \frac{\rho_w}{\mu_w}\frac{1}{R}\left(\frac{\tau_w}{\mu_w}\right)$$

DISCUSSION

The experimental values of the critical Reynolds number cluster about 600 although values as low as 200 have been observed[4]. At low speeds there appears to be no effect due to area suction[5] and at Mach numbers of 1·61 and 2·01 little effect of surface cooling[4]. It is suggested that a value of 600 be used to calculate the minimum height of roughness to promote transition and a value of 200 be used to determine the maximum height of roughness to avoid transition. A value of 600 has been used for a variety of configurations by N.A.S.A. for $M \leqslant 4$ and in all cases there was successful initiation of transition at the roughness elements[4].

In all hypersonic applications it is important to maintain a laminar boundary layer as far as possible to reduce the aerodynamic heating, therefore it is necessary to know the effect of roughness on transition in the presence of high heat transfer rates, pressure gradients sublimation, transpiration, burning of the surface, and so on. Of course the required experimental data does not exist, but the work already referred to suggests that the critical Reynolds number is fundamental to laminar boundary layers and likely to be insensitive to these other effects. Thus to a first approximation it should be possible to use the rule already proposed.

It should be remembered that there is a fundamental difference between the effects of two and three dimensional roughness elements on transition[1, 6].

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The Coefficient of Contraction in the Flow Through Perforated Plates

by

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THE COEFFICIENT of contraction of a jet of fluid flowing through an orifice has been widely studied in the field of hydraulics, using a jet of water discharging through an orifice into the atmosphere and measuring the area of the jet at the vena contracta. The coefficient of contraction C_c is then defined as:—

$$C_c = \frac{\text{area of the jet at the vena contracta}}{\text{area of the orifice}}.$$

The analytical determination of C_c has been restricted to two-dimensional flow; the first study, by Kirchhoff[1], deals with the flow through an opening in an infinitely large container, and gives the value of $C_c = \pi/(\pi+2) = 0{\cdot}611$. More recent work by von Mises[2] has dealt with two-dimensional flow with different boundary conditions *i.e.* the opening at the end of a duct (Fig. 1). The data for the two-dimensional case is shown in Fig. 2, where C_c is plotted for different geometries specified in Fig. 1.

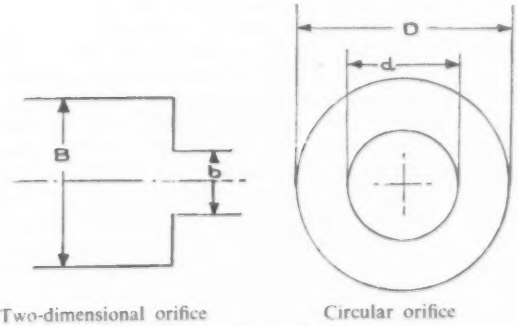
For the three-dimensional case, no analytical solution has been obtained, although it is probable that modern computing techniques could be used in this connection. A solution by a relaxation method is given by Southwell[3]. Rouse[4] has suggested that the results given by von Mises (Fig. 2) are also suitable for the three-dimensional flow through a circular orifice, provided that the ratio b/B of the plane case is replaced by the ratio d/D

where d = diameter of the orifice

D = diameter of the duct approaching the orifice.

This reasoning is based on the flow of a liquid through an orifice into the atmosphere, but similar ideas apply to the flow of a liquid into liquid or the flow of a gas through an orifice; in these cases, however, the actual value of C_c is more difficult to measure, due to the mixing which occurs at the boundary between the jet and the wake behind the orifice plate. The limited experimental data on this topic[5] has been analysed by Weinig[6], using free streamline potential theory with the assumption of zero wake velocity, to give a pressure drop coefficient.

$$K = \frac{\Delta p}{\frac{1}{2}\rho v^2} = \frac{[1 - C_c(1-s)]^2}{C_c^2(1-s)^2}$$



Two-dimensional orifice Circular orifice

FIGURE 1.

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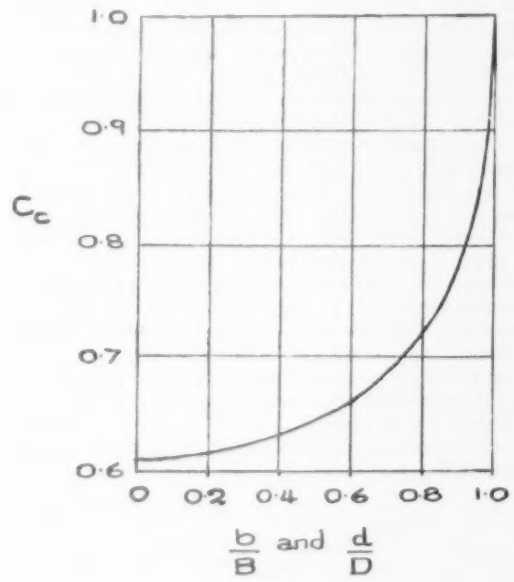


FIGURE 2.

where Δp = pressure drop over the orifice plate.

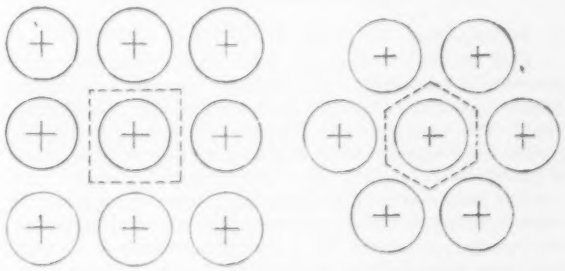
ρ = density of the fluid.

v = velocity of flow approaching the orifice plate.

s = solidity of the orifice plate *i.e.* $1 - \left(\frac{d}{D}\right)^2$

The results are important in connection with the flow through perforated plates, in which the pressure drop and the turbulence produced by the plate are important factors. The most common forms of perforated plate are those which have either a square or equilateral triangle pitch distribution (Fig. 3). In these cases, the flow through a given hole approaches from the region within the boundary indicated by the dotted line, instead of from a circular duct.

Preliminary experiments have recently been carried out to investigate the effect of this approach duct cross-section on the coefficient of contraction. An orifice plate was used



Square pitch Triangular pitch

FIGURE 3.

TABLE I
(*from* von Mises)

$\frac{b}{B}$ or $\left(\frac{d}{D}\right)^2$	C_c
0	0·611
0·1	0·612
0·2	0·616
0·3	0·622
0·4	0·631
0·5	0·644
0·6	0·662
0·7	0·687
0·8	0·722
0·9	0·781
1·0	1·000

with square and hexagonal shapes of approach duct arranged symmetrically about the axis of the orifice. For water flow, the value of C_c was easily measured, while for air flow an approximation to the value of C_c was made by use of a Pitot traverse downstream of the orifice.

The measurements show that the values of the coefficient of contraction C_c agree with those of Table I, provided that the ratio (area of orifice)/(area of approach) is used in place of $(d/D)^2$.

This is correct provided that the ratio (area of orifice)/(area of approach) is less than about 0·5. Above this value, the shape of the jet is influenced by the approach duct shape, and is no longer completely circular in cross-section, thus making an accurate determination of C_c impossible.

Thus in the flow through perforated plates, the effect of the adjacent holes on the coefficient of contraction for a given perforation may be considered by the use of Table I, provided the solidity of the plate is greater than 50 per cent.

Experiments are in progress to examine the flow through orifices of different geometries, with particular reference to the flow problems of heat exchangers. Another aspect of this interaction between adjacent orifices arises with the problem of high speed flow and the choking of orifices; experimental work on this is also planned.

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A Note on the Causes of Thin Aerofoil Stall

by

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RECENT RESEARCHES have led to some possible explanations for thin aerofoil stalling behaviour. Apart from the Owen Klanfer criterion these are the reverse flow breakdown hypothesis of McGregor and Wallis's turbulent separation theory.

This note describes simple theoretical boundary layer calculations which indicate the feasibility of Wallis's hypothesis. In addition the results of some experiments on a thin two-dimensional aerofoil with various leading edge configurations with Reynolds number, based on model chord, of 1·8 million and 1 million support either of these hypotheses, depending on the leading edge configuration. It is concluded that thin aerofoil stall can occur broadly, through either of the suggested mechanisms, depending on conditions in the nose region.

1. INTRODUCTION

Thin aerofoil stall is the result of the formation and subsequent breakdown of a "short" laminar separation bubble (sometimes called "nose stall") near the leading edge. The term "short" implies that the suction peak ahead of the bubble is virtually unaffected by the presence of the bubble.

This note attempts to assess the relative importance of some hypotheses which have been postulated as causes of the bubble breakdown. It is pertinent, therefore, to outline these hypotheses in some detail before presenting the results of the present note.

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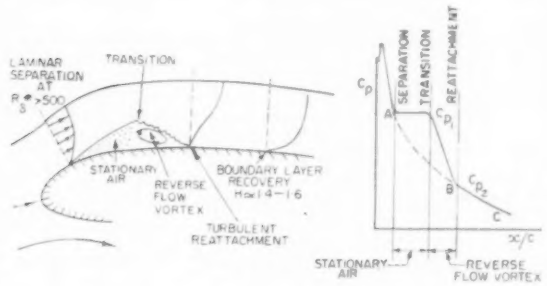
Until comparatively recently the Owen-Klanfer criterion[1] for the breakdown of the bubble reattachment process has been generally accepted. This criterion, based on experimental observations says that whenever the Reynolds number R_{δ^*} based on boundary layer displacement thickness exceeds a value near 400-500 the bubble is likely to be short, whereas if R_{δ^*} is smaller than this value the bubble is likely to be long. Figs. 1(*a*) and (*b*) show the structure of a short bubble with the characteristic reverse flow vortex and how this criterion might be interpreted.

Later researches have suggested to McGregor that the reverse flow vortex first expands (*see* Fig. 1(*c*)) and then disintegrates causing the short bubble to "burst." L. Crabtree[6, 7] makes the further suggestion that the breakdown occurs because of a limit to the amount of pressure that can be recovered in the reattachment process.

On the other hand Wallis suggests a fundamentally different hypothesis; this states that at moderate to high Reynolds numbers ($R_{\delta^*} \geqslant 500$) thin aerofoil stalling commences with a *turbulent* separation a short distance behind the bubble reattachment point. (*See* Fig. 1(*d*).) This separation point then moves rapidly forward with increasing incidence until it reaches the reattachment point of the bubble, thus bringing about a leading edge stall. At lower Reynolds numbers conditions immediately downstream of the reattachment of the laminar separation bubble play an important part in the onset and progress of the turbulent separation process.

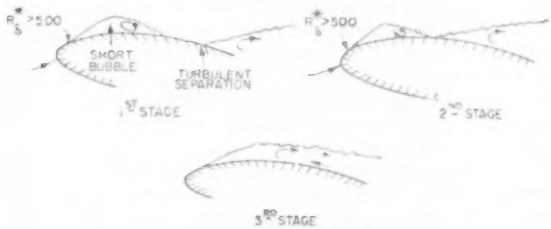
The investigations presented in this note were designed



(*a*) Structure of short bubble in unstalled flow.

(*b*) Nose stalled. Owen-Klanfer hypothesis.

(*c*) McGregor's hypothesis.



(*d*) Wallis's hypothesis.

FIGURE 1. The short bubble and possible causes of breakdown.

to compare the relative merits of the three hypotheses, and, in particular, to observe the turbulent separation process suggested by Wallis.

NOTATION

c aerofoil chord
C_p pressure coefficient on aerofoil surface $=(p-p_0)/q_0$
C_{p1} pressure coefficient at laminar separation point
C_{p2} pressure coefficient at reattachment point
H boundary layer shape parameter $=\delta^*/\theta$
p static pressure at a point on the aerofoil surface
p_0 free stream static pressure
q_0 free stream dynamic pressure
t aerofoil thickness
u local velocity inside boundary layer
U local velocity outside boundary layer
U_0 free stream velocity
x, y aerofoil co-ordinates along and normal to surface with origin at leading edge
δ^* boundary layer displacement thickness
θ boundary layer momentum thickness
σ pressure recovery coefficient $=\dfrac{C_{p2}-C_{p1}}{1-C_{p1}}$
α aerofoil incidence
R_{θ^*} Reynolds number based on δ^* and U

Suffixes m test model
surf test model surface

Reynolds number is based on aerofoil chord except where otherwise stated.

2. THEORETICAL CONSIDERATIONS

Wallis has concluded from his experiments, described in References 3 to 5, that thin aerofoil stall begins with turbulent separation behind the bubble, but so far he has never observed this type of separation. To establish therefore whether there is any real significance in his theory some preliminary calculations were carried out to determine the behaviour of the boundary layer shape parameter H after reattachment. An N.A.C.A. 64-A006 section, tested by McCullough and Gault[8] at a Reynolds number of $5{\cdot}8\times10^6$, based on model chord, was chosen and the Von Doenhoff-Tetervin[11] method applied to their experimental pressure distributions. The initial conditions H_0, θ_0/c were chosen as realistically as possible at $x=0{\cdot}015c$ where the post reattachment boundary layer recovery (*see* Fig. 1(*a*)) is assumed to have terminated. The choice of these quantities and the pressure gradients were based on experimental data in References 8 to 10. In particular, when boundary layer control is absent, the recovery is assumed to be incomplete, *i.e.* values of H_0 near 1·6 were chosen rather than 1·4. The chordwise growth of H at incidences from 2 to 4·5 degrees and the corresponding pressure gradients are shown in Figs. 2 and 3.

From these results some tentative conclusions can now be drawn. For fixed values of H_0 and θ_0/c the H values increase for a few per cent chord and then decrease; there is therefore a maximum value behind the bubble.

As incidence increases H_{max} increases and hence may reach a value large enough for separation. The value of H_{max} increases if θ_0/c or H_0 increases, that is to say deteriorating conditions at, or immediately after, reattachment render separation more likely. The position of H_{max} appears to be almost independent of θ_0/c but strongly dependent on H_0, moving back with decreasing values of H_0. Hence conditions at the bubble, especially the value of H_0, appear to play an important part in the onset of separation.

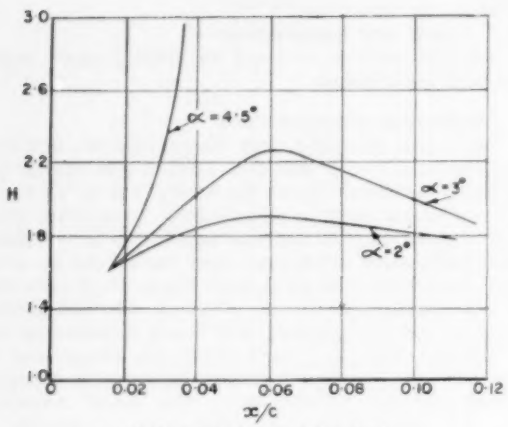
If θ_0 is assumed to be inversely proportional to Reynolds number, an assumption which McGregor has found to be roughly true, it is easy to show that H_{max} is reduced, that is to say separation is delayed by increasing Reynolds number. This explains the familiar scale effect on aerofoils with short leading edge bubbles. These calculations suggest therefore that a turbulent separation a short distance behind the bubble is possible, and that it is influenced by conditions at the bubble, hence they support Wallis's hypothesis.

3. DESCRIPTION OF APPARATUS AND TESTS

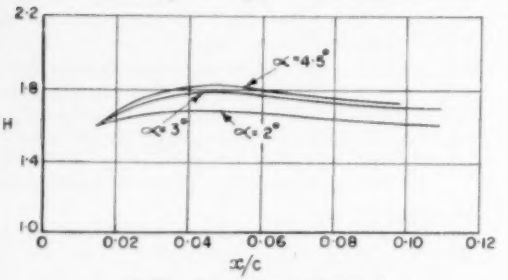
3.1. *Apparatus*

The tests were conducted in two open circuit tunnels, respectively with 3 ft. × 1 ft. and 1 ft. × 1 ft. working sections, at the University of Southampton. The latter had a 4:1 contraction ratio and a set of turbulence reducing screens at the entrance to the contraction section. It offered a higher test Reynolds number with lower stream turbulence than the 3 ft. tunnel and was therefore chosen for most of the tests.

The model was constructed by fairing a 6 in. chord metal aerofoil (Fig. 4(*a*)) 6 per cent thick with 3 per cent camber at 40 per cent chord to a wooden plate giving an overall chord of 29½ in. The model spanned the working

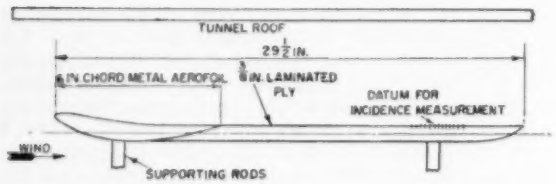


(*a*) $H_0 = 1{\cdot}6$, $\theta_0/c = 0{\cdot}53 \times 10^{-3}$



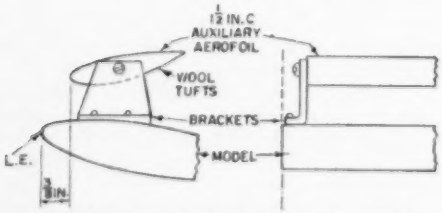
(*b*) $H_0 = 1{\cdot}6$, $\theta_0/c = 0{\cdot}15 \times 10^{-3}$

FIGURE 2. Calculated chordwise growth of H after reattachment on a N.A.C.A. 64A006 aerofoil. $R = 5{\cdot}8 \times 10^6$.



(*a*) Raised nose model in the 1 ft. sq. tunnel.

(*b*) Drooped nose model (3 ft. × 1 ft. tunnel).



(*c*) Raised nose model with auxiliary aerofoil.

FIGURE 4. Diagram of model and test configurations in the 1 ft. sq. and 3 ft. × 1 ft. tunnels.

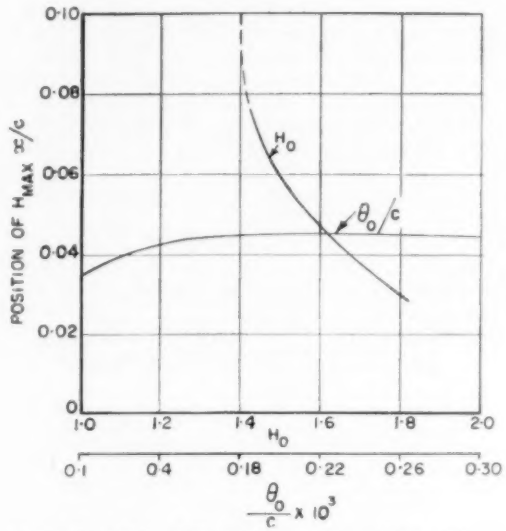


FIGURE 3. Effect of H_0 and θ_0/c on the position of H_{max}.

sections of both tunnels so as to simulate two-dimensional flow conditions. The model could be mounted either "drooped nose" or "raised nose" as shown in Figs. 4(*a*) and 4(*b*) respectively. Provision was also made to mount an auxiliary aerofoil on the model as shown in Fig. 4(*c*). In order to detect stalling of the auxiliary aerofoil and hence set it near maximum lift incidence tufts were attached to its trailing edge.

A simple static pressure probe was used for pressure measurements. The boundary layer investigations were carried out using a Pitot-static device. The long probes were designed to reduce interference to a minimum. Pressure readings were taken with an inclined manometer, and a Cambridge precision pressure gauge was used for finer measurements. Model incidences were measured with a clinometer placed near the trailing edge.

3.2. *Description of Tests*

Pressure and boundary layer measurements together with liquid film (lampblack and paraffin) flow visualisation studies were conducted over a small range of incidences up to the nose-stall. Further studies were made using the auxiliary aerofoil of 1½ in. chord by ⅛ in. thickness. For each model incidence selected, the auxiliary aerofoil was set at an incidence just below its stall. This reduced the adverse pressure gradients close to the leading edge of the test aerofoil but increased these gradients farther downstream.

The test Reynolds numbers were respectively 1×10^6 and $1{\cdot}8 \times 10^6$ for the 3 ft. × 1 ft. and 1 ft. × 1 ft. tunnels.

4. RESULTS

4.1. *"Raised" and "Drooped" nose models*

Pressure distributions for the drooped nose and raised nose configurations are shown in Figs. 5, 6 and 7 which show the constant pressure and pressure recovery regions, revealing the presence of the bubble. The length and position of these regions approximately locate the laminar boundary layer-stationary air zone and the reverse flow vortex. The behaviour of the bubble for the drooped nose configuration (Fig. 5) is plotted in Figs. 8 and 9. Fig. 8 shows a rearward movement of the reattachment point

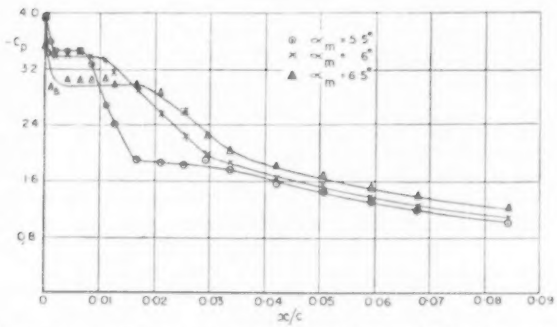


FIGURE 5. Pressure distributions just before and after the nose stall. Drooped nose $R=1\times10^6$. 3 ft.×1 ft. tunnel.

with increasing incidence, this movement being revealed by the lampblack patterns as well as the pressure distributions. Although these curves in Fig. 8 do not agree, they show that short bubble breakdown has commenced with a large expansion of the reverse flow vortex, preceded by an enlargement of the constant pressure region (Fig. 9). With increase of incidence α_m, it has been found that, before the expansion commences, the pressure recovery coefficient $\sigma=(C_{p2}-C_{p1})/(1-C_{p1})$ (Fig. 10) increases, but, near the beginning of the expansion, it becomes nearly constant at a value near 0·37.

The pressure distributions for the raised nose configuration in the 3 ft. × 1 ft. tunnel are shown in Fig. 6. Adverse gradients now appear downstream of the bubble and the nose stall is more severe than for the drooped nose configuration, with only a slight reverse flow expansion occuring at $\sigma\simeq0{\cdot}36$. The pressure distributions in the 1 ft. sq. tunnel (Fig. 7) are similar to those in the 3 ft. × 1 ft. tunnel but the reverse flow expansion is rather more pronounced.

The results of boundary layer surveys, compared with the Von Doenhoff-Tetervin theory are presented in Fig. 11. The H distributions, determined from graphical integration of the boundary layer profiles, show common features over the incidence range, namely an initial region of rapid recovery, followed by a rise in the H values up to $x/c=0{\cdot}03$ and then a decrease in the values; they therefore show maximum values near $x/c=0{\cdot}03$. Increase

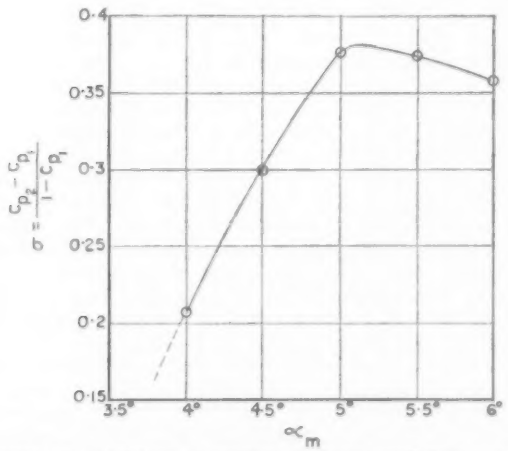


FIGURE 10. Variation of pressure recovery coefficient σ with incidence. Drooped nose. $R=1\times10^6$. 3 ft.×1 ft. tunnel.

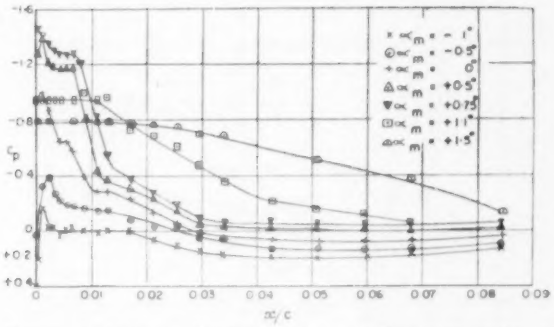


FIGURE 6. Pressure distributions over leading edge region of model. Raised nose. $R=1\times10^6$. 3 ft.×1 ft. tunnel.

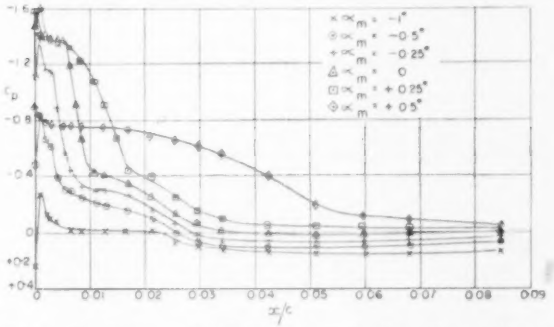
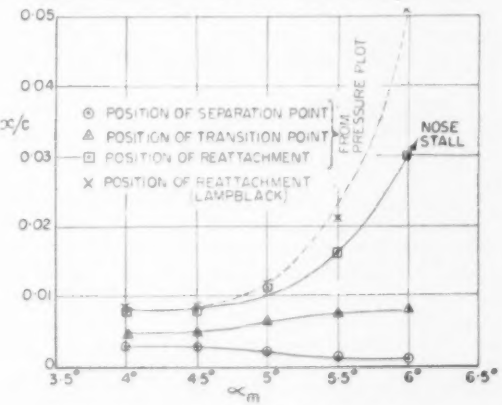
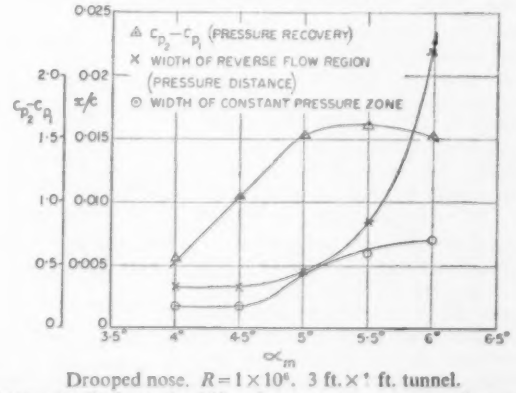


FIGURE 7. Pressure distributions over leading edge region of model. Raised nose. $R=1{\cdot}8\times10^6$. 1 ft. sq. tunnel.



Drooped nose. $R=1\times10^6$. 3 ft.×1 ft. tunnel.

FIGURE 8. Estimated separation, transition and reattachment points plotted against α_m.



Drooped nose. $R=1\times10^6$. 3 ft.×1 ft. tunnel.

FIGURE 9. Estimated width of constant pressure and reverse flow zones compared with pressure recovery.

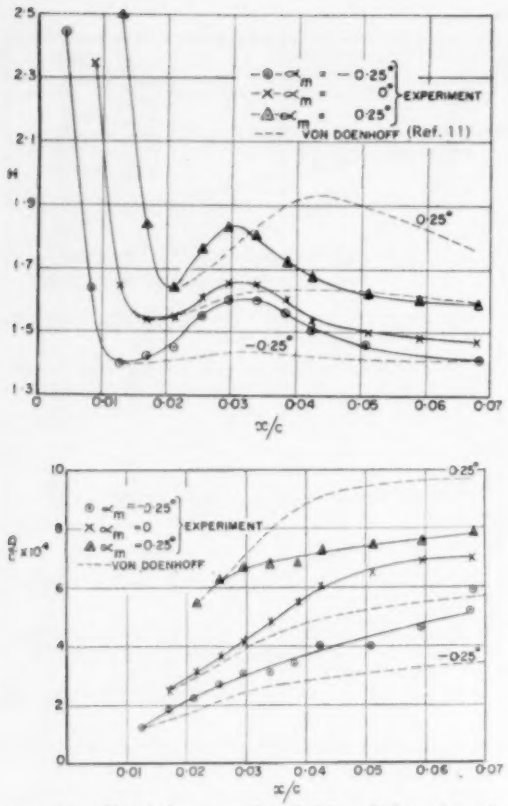


FIGURE 11. Chordwise growth of H and boundary layer momentum thickness over the leading edge region of test model. Raised nose. $R=1{\cdot}8\times10^6$. 1 ft. sq. tunnel.

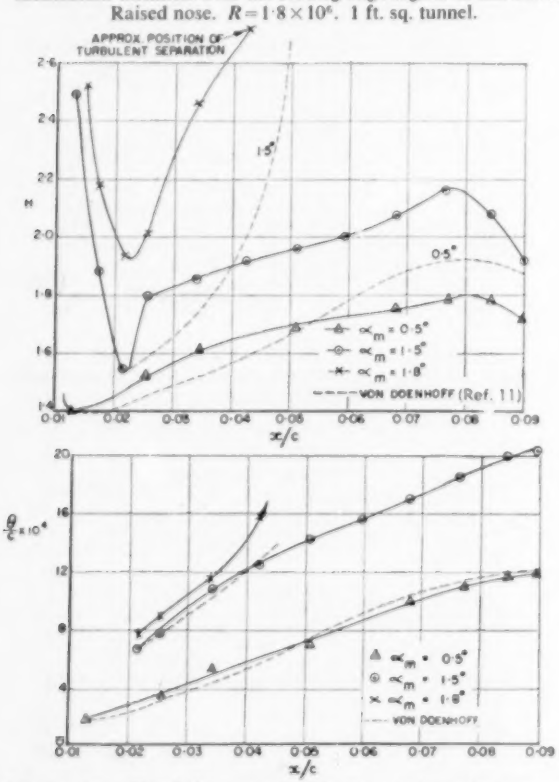


FIGURE 13. Chordwise growth of H and boundary layer momentum thickness over leading edge region. Raised nose with auxiliary aerofoil in 1 ft. sq. tunnel. $R=1{\cdot}8\times10^6$.

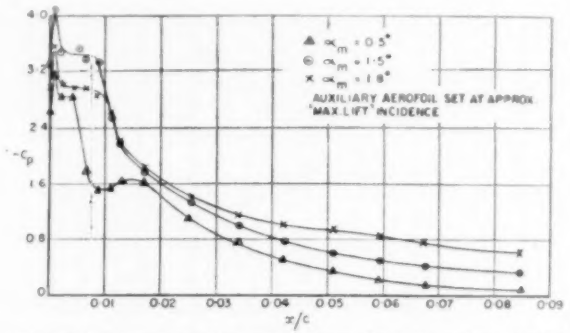


FIGURE 12. Pressure distributions over the L.E. region. Raised nose with auxiliary aerofoil in 1 ft. sq. tunnel. $R=1{\cdot}8\times10^6$.

of incidence results in an increase of momentum thickness θ_0 and of H_0 with a corresponding rise in H_{max}. The final value of H before breakdown, near 1·9, is within the range Wallis suggests for separation.

4.2. *Effect of Transition wire on "raised-nose" model*

In addition to the boundary layer and pressure measurements described, a separate test on the "raised nose" model was carried out to study the effect of a 16 s.w.g. wire placed at $x/c=0{\cdot}03$ on the flow over the surface. A liquid film flow pattern showed that the wire produced a limited separation region downstream of itself which had no effect on the bubble and therefore no effect on the nose stall.

4.3 *Model with Auxiliary Aerofoil*

Pressure distributions with the auxiliary aerofoil in position, which showed higher suction peaks and delayed breakdown of the bubble are presented in Fig. 12. The kink behind the bubble at $\alpha_m=0{\cdot}5$ is probably due to the influence of the auxiliary aerofoil. The corresponding boundary layer behaviour is shown in Fig. 13. The H distributions are somewhat similar for $\alpha_m=0{\cdot}5$; 1·5° for $x/c>0{\cdot}03$ while liquid film studies indicate that the flow remains attached even at a value of H_{max} near 2·2. At $\alpha_m=1{\cdot}8°$ however, the initial recovery behind the bubble becomes less complete and H increases rapidly until it passes above 2·6, suggesting a turbulent separation. (*Note*: It was not possible to evaluate H beyond this point owing to the limited vertical movement of the boundary layer probes.) This separation is confirmed when the experimental methods, which here include surface velocity measurements, are compared in Fig. 14. The lampblack pattern (Fig. 14) reveals a heavy accumulation of liquid, followed by a "half herring bone" appearance indicating the bubble. Beyond this region a mottled pattern, corresponding with positive surface velocities persists as far as $0{\cdot}04c$ where there is another mild accumulation. Behind the accumulation the mottled pattern reappears up to about $0{\cdot}1c$ but with negative surface velocities. Hence the accumulation near $0{\cdot}04c$ is apparently caused by liquid within the zone $0{\cdot}04-0{\cdot}1c$ being swept upstream by a reverse flow underneath a turbulent separation. The thin deposit between $x/c=0{\cdot}1$ and 0·12, followed by a mottled pattern with positive velocities, indicates another reattachment thus forming a second and much larger bubble. The pressure distribution in Fig. 14 shows a faint suggestion of constant pressure and pressure recovery regions from $x/c=0{\cdot}04$ to $x/c=0{\cdot}1$. Further increase of incidence results in flow breakdown with a long bubble extending over the first 15 per cent chord.

5. DISCUSSION

For all tests in which a reverse flow expansion has been observed, a comparison of values of the pressure recovery coefficient σ_{max} with values derived from other work leads to the results shown in Table I.

The table shows that, although there are various degrees of expansion, the pressure recovery coefficient attains a maximum value, just before the breakdown of short bubble flow and that the value is nearly constant. This is consistent with Crabtree's suggestion in Ref. 7 that σ has a maximum value in short bubble flow.

This result suggests the following modification to McGregor's reverse flow expansion hypothesis. When a short bubble forms σ increases with incidence until it attains a maximum near 0·36. The reverse flow vortex then expands until the prevailing pressure gradients are such that $\sigma_{required}$ becomes greater than σ_{max} which condition prevents reattachment via a short bubble. The argument is more easily understood by referring to the pressure distribution diagram in Fig. 1(*a*), where the prevailing pressure gradients are defined by the curve *ABC*. The portion *AB* follows the dotted line if the flow is completely attached. The coefficient σ controls the available recovery $C_{p_2}-C_{p_1}$ and if the gradients are too severe C_{p_2} will not lie on the dotted curve *ABC* and hence reattachment is not possible.

It follows that, provided the downstream pressure gradients are favourable, that is to say, if *C* lies above *B* one can expect a more gradual change over from a short to a long bubble since $(C_{p_2}-C_{p_1})_{required}$ will not increase with continued expansion. On the other hand adverse pressure gradients $(C_{p_2}-C_{p_1})_{required}$ permit little or no expansion, a deduction which is consistent with the present observations.

The delay of nose stalling with increase of Reynolds number can be explained in the light of these results, since a corresponding reduction of bubble length makes it easier to satisfy the condition $\sigma_{required} \lesssim \sigma_{max}$.

The "raised nose" tests showed that turbulent separation was not actually achieved on the test model until the auxiliary aerofoil was installed. In this instance the *H* distributions (Fig. 13) and the flow diagram (Fig. 14) suggest that separation had started near $x/c=0{\cdot}08$ at $\alpha_m=1{\cdot}5°$ and had moved forward to $x/c=0{\cdot}04$ at $\alpha_m=1{\cdot}8°$.

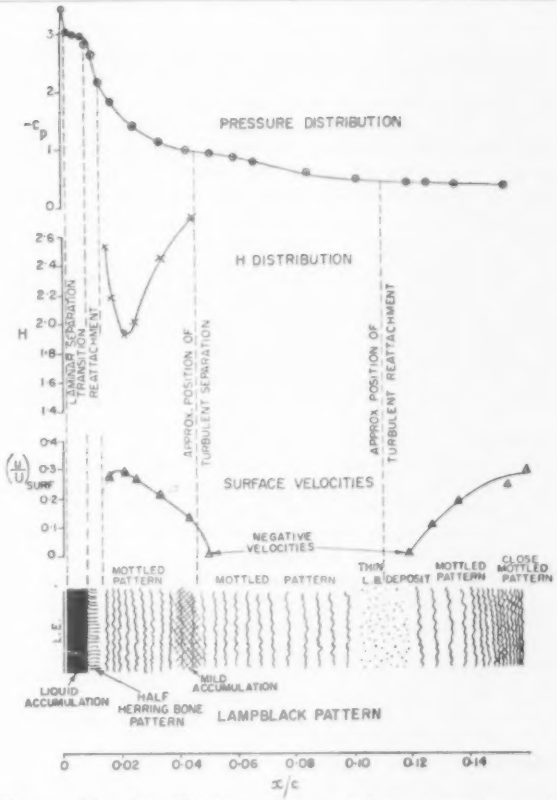


FIGURE 14. Identification of a turbulent separation and reattachment on the model with auxiliary aerofoil. $\alpha_m=1{\cdot}8°$. $R=1{\cdot}8\times10^6$.

It is evident therefore, that on the test model with the auxiliary aerofoil the turbulent separation starts near $x/c=0{\cdot}08$, and then, with increasing incidence moves rapidly towards the downstream edge of the bubble. The pressure gradients which have brought about this mode of stall are not far different from those near the leading edge of a thin aerofoil.

The experimental evidence supports Wallis's hypothesis as well as confirming that the calculations are in qualitative agreement with results. The *H* value for imminent separation appears, however, to be near 2·6 rather than Wallis's suggested value near 2·0.

It appears that the onset of short bubble breakdown can, apart from Owen's criterion, result from reverse flow expansion. Whether it can happen depends primarily on Reynolds number and the prevailing pressure gradients ahead of laminar separation, within, or just downstream of

TABLE I

Reference	*Model*	$\sigma_{max.}$	*Degree of Expansion*	*Pressure Gradient after Reattachment*
	Drooped Nose 3 ft. × 1 ft. tunnel	0·37	Large	Favourable
	Raised Nose Test Model 1 ft. tunnel	0·36	Moderate	Adverse
	Raised Nose Test Model 3 ft. × 1 ft. tunnel	0·36	Small	Adverse
2	Cylindrical Nose Aerofoil	0·35	Moderate	Adverse
2	Piercy Aerofoil $t/c=10$ per cent	0·36	None	Adverse and Severe
10	Modified N.A.C.A. Aerofoil $t/c=10$ per cent $R=1{\cdot}5$ to 3×10^6 $R=$ 4 to 6×10^6	 0·34 0·32 to 0·34	 None None	 Adverse and Severe Adverse and Severe
10	N.A.C.A. 663018 $R=1{\cdot}5$ to 3×10^6	0·34 to 0·36	None	Adverse and Severe

the bubble. It is also possible that thin aerofoil stall can be brought about by turbulent separation, either through increasing adverse pressure gradients and/or increasing values of θ_0 and H_0 following reverse flow expansion at the rear of the bubble. However these experiments do not at this stage eliminate the possibility that conditions for turbulent separation may never arise on a thin aerofoil in flight.

6. CONCLUSIONS

A turbulent separation has been observed, on the test model with an auxiliary aerofoil, immediately before the nose stall. As suggested, this result is not yet conclusive.

Boundary layer calculations do show that if suitable conditions arise a turbulent separation is possible on a thin aerofoil, for example the N.A.C.A. 64A006 section.

The investigation leads to the following tentative conclusions:—

(*i*) Thin aerofoil stall can, as an alternative to the Owen-Klanfer hypothesis, result from turbulent separation behind the bubble, while conditions at reattachment as well as the pressure gradients play an important part in the onset of separation.

(*ii*) The reattachment process can fail, even if the Owen-Klanfer criterion is satisfied, because of reverse flow expansion which commences when $\sigma=(C_{p_2}-C_{p_1})/(1-C_{p_1})$ attains a value near 0·36. The expansion continues until the pressure recovery required exceeds the maximum obtainable in the reattachment process ($\sigma\simeq 0{\cdot}36$) when the bubble then bursts.

To establish more definitely the causes of thin aerofoil stall further studies are required, especially as the turbulent separation hypothesis is still in doubt when applied to a thin aerofoil in flight.

ACKNOWLEDGMENTS

The author wishes to thank Professor E. J. Richards of the University of Southampton for his help and encouragement throughout the course of this study, also the Workshop Staff for their assistance in the Wind Tunnel experiments. The author also wishes to thank Mr. R. A. Wallis for his contribution when he visited the University during the 1955-56 session.

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Wakes in Axial Compressors

BY W. F. WILES*
(Aero Engine Division, Rolls-Royce Ltd.)

THE note in the July JOURNAL by H. Pearson and A. B. McKenzie (p. 415) shows that the flow into an axial compressor is nearly at a constant velocity at all points in the entry plane; and that if a wake of low energy air is fed into it, the compressor reduces the static pressure locally in this wake, in such a way as to tend to preserve constant velocity over the whole face. This raises two important questions on the investigations of flow in the air intake supplying the compressor:—

(*i*) First, whether intake model tests without an engine are of any value. These tests are done normally with a fan drawing air through the model from a long way downstream; or, in some cases in the wind tunnel under flight conditions, with the intake duct discharging back into the tunnel flow. This results in a nearly uniform static pressure across the compressor face; although with an intake giving a bad flow, there is usually a gradient with low static pressure in the same region as low total pressure, *i.e.* the same sort of gradient which the engine seeks to impose, but not so great.

Now if it were possible to introduce a "model" engine, and hence a change in local static pressure, the flow would be changed in the following ways. In the low energy regions, the static pressure would be reduced and hence there would be a less unfavourable pressure gradient in the direction of flow immediately upstream, which could in some circumstances result in an improvement such as the reduction or suppression of a breakaway.

The flow would be curved, giving an inflow into the low energy regions, *i.e.* it would introduce some swirl into the intake flow.

However, there are two factors which will tend to keep these effects small—firstly, as pointed out above, a bad intake flow already has a small static pressure gradient and this will diminish the effect of the engine; and secondly, the pressure gradient cannot be felt very far upstream—and in most intakes, the last diameter or so of

*This note represents the view of the author and does not necessarily reflect that of the company.

Received 26th October 1959.

the intake is a parallel sided or contracting duct, where a change in pressure gradient should not be so important.

Provided care is taken in the interpretation of model tests, it seems that the results should not be misleading; although obviously it is worth trying to represent the engine when possible by such devices as a freely rotating windmill or a gauze, immediately behind the plane of instrumentation.

(*ii*) The second question raised is whether the present criteria by which we judge intake flow are adequate. Pearson and McKenzie's note shows that as far as blade vibration is concerned, the ratio V_{max}/V_{mean} is not. In any case, this is not satisfactory now that it has been shown that velocities at the compressor face depend on whether an engine is present.

The distortion index discussed in Ref. 1 is better. However, this is awkward to use in practice because it is a function of engine mass flow and its value will depend on the r.p.m. at which the engine is sensitive to the flow distortion—which normally covers a range of values.

We would suggest that to obtain a measure of the blade excitation to be expected, the quantity $(P-P_{mean})/(P_{mean}-p_{mean})$ should be plotted against angular position round the compressor face for a particular radius; and a Fourier analysis of this graph will give the compressor blade excitations of various engine order frequencies[2].

As far as effects on engine handling are concerned, we suggest the number $(P_{max}-P_{mean})/(P_{mean}-p_{mean})$. This has the advantages that it does not depend on engine mass flow; nor does it depend on P_{min}, which is a function of how close to the duct wall measurements are taken.

It is necessary to quote with this number the shape of flow distortion it describes, *e.g.* low energy region distributed round the outer circumference. It is desirable to have one number which takes due account of this—such as the standard dispersion of total head readings as used by Dr. Seddon at the R.A.E. Farnborough. But there is evidence to show that different engines react differently to different types of distortion, and therefore it is not possible to have a number which would be universally acceptable.

NOTATION

V_{max} maximum velocity measured at compressor face
V_{mean} mean velocity measured at the compressor face
P total pressure measured at the compressor face
P_{max} maximum value of total pressure measured anywhere on the compressor face
p_{mean} static pressure at the compressor face calculated from the mean total pressure and mass flow
P_{mean} mass flow weighted mean value of total pressure at the compressor face
P_{min} minimum value of total pressure measured anywhere at the compressor face.

(*Note*: the definition of P_{mean} is difficult in circumstances where the mass flow distribution across the compressor face is different in the model from the full scale intake with engine. However, the mass flow weighted mean still appears to be the best quantity to take.)

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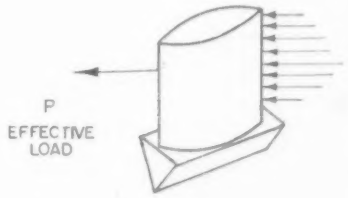
Damage to Axial Compressors

A. COLES, A.F.R.Ae.S.

I WOULD like to point out a possible ambiguity in the paper by J. Dunham, in the October issue of the JOURNAL. When considering the relative stresses in similar steel and aluminium alloy blades the author states that for blades "doing the same duty" the maximum stress in the steel blade is three times that in the aluminium type. This would seem to be true only if both blades are made to vibrate with the same tip amplitude, whereas the term "doing the same duty" implies withstanding the same air loading, and consequently the steel and aluminium alloy blades would suffer different deflections.



$$\sigma = \frac{My}{I}$$

for effective
M = constant
σ depends on
y/I only.

From a simple consideration of the stressing of any two similar blades, subjected to the same loading conditions, the stress is dependent on section properties only, and would therefore be the same in both materials.

The form of the stress equation in general use for blades is:

$$\sigma = k\sqrt{(E\rho)}\,\nu a$$

where k constant depending on section properties etc.
E Young's modulus
ρ density
ν frequency
a amplitude

Received 6th November 1959.

REPLY BY JOHN DUNHAM, Grad.R.Ae.S.

I ASSUMED that the value (maximum tip amplitude × frequency) of a vibrating blade is determined by the airflow over it, and not by the blade material. This can be shown[1] to be true for blades in which aerodynamic damping greatly exceeds the damping due to material hysteresis and mechanical friction in the blade root. Briefly, the resonant amplitude adjusts itself so that the net energy supplied by the air flow is zero, and the material properties are not involved. In general, any vibration in which the aerodynamic damping falls below zero (*i.e.* flutter) is so dangerous that it must be eliminated in the development stage, so the tip amplitude rule would be expected to hold in a production engine. It cannot be asserted that blade vibration under rotating stall conditions is fully understood, however, and exceptions to the rule have been found[2].

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Graduates' and Students' Section

The Flight Testing of Rotorcraft

The Test Pilot Lecture for the 1959-60 Lecture Session was given on 11th November by Squadron Leader W. R. Gellatly, Senior Rotary Wing Test Pilot of Fairey Aviation Ltd., and one of the most experienced helicopter pilots in Britain.

There is no basic difference between flight testing fixed or rotating winged aircraft, the lecturer stated, they both rely upon aerodynamic lift. The fixed wing aircraft programme is fairly well defined from long experience, however, serious development of rotorcraft is relatively new being approximately fifteen years old. In that time machines have developed from slow and costly two place contraptions to a sixty-five passenger VTOL airliner competitive in costs and speed with many short-haul fixed wing aircraft. The large variety of rotorcraft types is at last settling down into three main configurations:— single rotor/tail rotor and two rotors in tandem for pure helicopters, shaft drive turbines, and in the convertiplane field, some form of rotor unloaded onto a fixed wing for cruise with tip power for take-off and landing.

The major differences between fixed and rotating winged aircraft in performance measurement are caused by the following properties of the rotary wing aircraft:—

(*a*) the reversed power/speed law below V_{imp},
(*b*) relatively poor stability characteristics,
(*c*) the greater number of variables with which the pilot has to contend.

The classic performance work on levels, climbs and glides is measured exactly as on fixed wings however, in addition, during ceiling climbs compressibility effects restrict rotor control margins. Constant speed engine governors or tip jet drive can be used to overcome this by reducing rotor r.p.m. with altitude giving a constant true tip speed.

The aim of handling tests is the same for all flying machines; to ensure that they do their job safely and, if possible, comfortably as well, *i.e.* to develop-out any dangerous features. With new aircraft the pilot's job starts in the design stage when he will be consulted on all aspects of controls, equipment and the layout of the cockpit. Certain aircraft have power systems specially developed for that type and this involves introductory "flying" in special rigs to give full familiarity. Features peculiar to rotorcraft in so far as handling is concerned are:—

(*a*) flight handling tests start on the ground—the aircraft is "alive" when the rotor is started,
(*b*) the possibility of destructive ground resonance—caused by the natural frequencies of rotor and structure coming into sympathy and without damping becoming divergent.

Once the flight programme is under way, handling tests will follow the classic pattern. The speed and height envelope is opened progressively with control behaviour and elementary stability checks being made at each advance, together with comprehensive strain gauging. The working flight envelope is built up, in terms of speed, height and manoeuvrability, from these results combined with the performance results.

On rotorcraft, tests have to be made of autorotative performance and the "Deadman's Curve" established, *i.e.* the minimum safe speed and height from which the aircraft can be landed following power failure. Operational tests have to be made establishing confined space and vertical flight performance both by day and night.

The whole programme depends on the adequate instrumentation of the aircraft and the responsible analysis of the results. Most important is the flight development team, which includes the pilot. This team, being composed of human beings, must be imbued with mutual respect and confidence if it is to produce a winner.

Squadron Leader Gellatly concluded by suggesting that by producing automatic devices, which will eliminate many of the human restrictions, we would finally attain full all-weather operation. This will put more onus on the human qualities of the flight development teams to ensure a practical result, and, would result in long careers test flying VTOL aircraft in the future for any of those who are "crazy enough to enter the profession."—W.G.W.

Squadron Leader W. R. Gellatly, A.F.C. in the prototype Fairey Rotodyne.

January Lecture

The first lecture of the Spring Session, on Wednesday 13th January is to be given by Wing Commander F. Latham of the R.A.F. Institute of Aviation Medicine and will be entitled "Aviation Medicine in the Space Age."

New Visits Secretary

Mr. N. R. Craddock will be the Sections' Visits Secretary after December 1959, and all applications for visits should then be sent to him at:— 5 Oxleay Road, Harrow, Middlesex.

Cranfield—not Cranwell

By mistake last month we said that the College of Aeronautics was at Cranwell instead of Cranfield. Apologies to both.

THE ROYAL AERONAUTICAL SOCIETY—AUSTRALIAN DIVISION

Annual Report for the Year Ended 31st December 1958

THE Council of the Division has pleasure in presenting the Annual Report of the Australian Division for the year ended 31st December 1958.

Fellowship

Another member of the Division, Dr. E. G. Bowen, O.B.E., was honoured during the year by election to Fellowship, whose numbers now amount to 16. Dr. Bowen is Chief of the Division of Radiophysics of the Council for Scientific and Industrial Research Organisation and is widely known, not only throughout Australia but also in other parts of the Western world for technical advances developed under his guidance.

Council

The Council elected following the postal ballot is: —

President: Mr. M. M. Waghorn, A.F.R.Ae.S.

Past President: Mr. L. P. Coombes, F.R.Ae.S.

Honorary Secretary and Treasurer: Mr. W. Isbister, A.F.R.Ae.S.

Council: Mr. F. R. Green, A.F.R.Ae.S., Mr. R. J. Ifield, A.F.R.Ae.S., Mr. A. F. W. Langford, A.F.R.Ae.S., Dr. R. R. Shaw, A.F.R.Ae.S., Mr. J. L. Watkins, F.R.Ae.S., Mr. L. C. Williams, A.F.R.Ae.S., Professor W. H. Wittrick, A.F.R.Ae.S.

In addition, the following representatives were appointed by the Branches: —

Mr. D. A. Ashover, A.F.R.Ae.S., and Mr. W. Downes, A.F.R.Ae.S. (Sydney Branch); Mr. F. W. David, F.R.Ae.S., and Mr. G. D. Dawson, F.R.Ae.S. (Melbourne Branch); and Mr. R. P. Bonnell, A.F.R.Ae.S., and Mr. R. J. Rockliff, A.F.R.Ae.S. (Adelaide Branch).

Trustees: Messrs. L. P. Coombes and W. Isbister.

Meetings

Three Council meetings were held during the period of office of the present Council. In addition, three Councillors available in Sydney early in October held discussions with a member of Council of the parent body—Mr. S. Scott Hall, F.R.Ae.S. The President, Mr. Waghorn, entertained guests in the President's enclosure at the Air Display at Camden, N.S.W., mentioned in Branch activities.

Branch Activities

SYDNEY BRANCH

Chairman: Professor W. H. Wittrick, A.F.R.Ae.S.

Hon. Secretary: D. A. Ashover, A.F.R.Ae.S., c/o Qantas Empire Airways, Hunter Street, Sydney.

Hon. Treasurer: L. R. Carolan, A.F.R.Ae.S.

This Branch has had a successful year with its membership increasing by 57 from 389 to 446. Forty-one of these were Branch members, the remainder being Division members. Twelve General Meetings with an average attendance of 81 were held, and two visits were made during the year. However, the outstanding activity of the year was the fourth Air Display held by the Branch. This took the form of a public display at the Camden Aerodrome in conjunction with the Royal Aero Club of N.S.W. on the 15th November. The Divisional President, Mr. M. M. Waghorn, acted as Host to the Branch's guests. The attendance was approximately 2,500 and the Display was generously supported by the Royal Australian Navy and the Royal Australian Air Force, as well as by the Aircraft Industry.

MELBOURNE BRANCH

Chairman: F. W. David, F.R.Ae.S.

Hon. Secretary: N. J. Munro, A.F.R.Ae.S., c/o Aeronautical Research Laboratories, Box 4331, G.P.O. Melbourne, Victoria.

Hon. Treasurer: D. A. Gibson, A.F.R.Ae.S.

This Branch has 160 Division members and 107 Branch members, making a total of 267. Nine meetings were held during the year. Initial steps were taken by some members of this Branch to form a Helicopter Sub-Branch.

ADELAIDE BRANCH

Chairman: R. J. Rockliff, A.F.R.Ae.S.

Hon. Secretary and Hon. Treasurer: J. A. Cartmel, A.F.R.Ae.S., Box 1424 H, G.P.O. Adelaide, S.A.

Membership of this Branch has increased by four during 1958—from 102 to 106. Nine meetings were held during the year with an average attendance of 31. The highlight of the year was the Inaugural Sir Ross and Sir Keith Smith Memorial Lecture, given on the 28th April by Sir Hudson Fysh, F.R.Ae.S., entitled "December 19th 1919." In addition, a social evening was held in the form of a dance and a barbecue supper.

Meetings

The following meetings were held during the year by the Branches: —

SYDNEY BRANCH

Some Techniques and Applications of Closed Circuit Television	Mr. J. E. Benson
Artificial Satellites	Mr. A. P. Mackerras Mr. R. E. Aitchison
Airport Development in Australia	Mr. K. N. E. Bradfield
Recent Developments in High Speed Wind Tunnel Testing	Prof. L. C. Woods
The Woomera Rocket Range	Mr. T. F. C. Lawrence
Airworthiness and the A.R.B.	Mr. R. E. Hardingham (& Melbourne)
On His Aviation Experiences	Capt. O. P. Jones
Design for Safer Landing	Mr. R. W. Cummings
Aviation in Papua, New Guinea	Mr. J. S. Arthur
The Heat Barrier	Prof. W. H. Wittrick (& Melbourne)
Commonwealth Aeronautics—Where are we Heading	Sir Roy Fedden

MEMBERSHIP

	Numbers as at 1-1-58	New Members added	Net Grade Transfers	Net Division Transfers	Resigned or died deleted	Numbers as at 31-12-58
Fellow	15	—	1	—	—	16
Associate Fellow	147	6	22	1	2	174
Associate	76	9	2	3	1	89
Graduate	52	1	−14	1	—	40
Student	46	12	−9	−1	3	45
Companion	10	2	−2	−1	—	9
TOTAL	346	30	—	3	6	373

MELBOURNE BRANCH

The Airline Fleet	Mr. J. L. Watkins
High Speed Aerodynamics	Mr. F. G. Blight
Some Aspects of Flying Operations in Airlines	Capt. R. E. Bailey
Air Traffic Control in Australia (Lawrence Hargraves Memorial Lecture)	Mr. R. M. Seymour
Australian Air Maritime Operations	S./L. Michael
Air Crew Escape Systems	S./L. Buley
	S./L. Morrison
Some Experiences of a Pioneer in the Aircraft Industry in Australia	Sir Lawrence Wackett

ADELAIDE BRANCH

The International Geophysical Year with reference to high altitude rockets and satellites	Dr. F. W. Wood
Electronic Digital Computers	Dr. J. A. Ovenstone
Naval Air Power	Cdr. R. H. Hain
Looking at High Speed Flow	R. Cartwright
	J. Cartmel
The Australian Short Range Radio Navigation System	E. Stern
The Air Defence Problem	T. Dalton-Morgan

In addition, film nights continued to draw a good attendance of members and their families.

Membership of the Division

Total membership has increased from 346 to 373—a rise of nearly eight per cent for the year. Associate Fellows and Associates increased 18 and 19 per cent respectively and the Graduate and Student grades decreased 23 and 2 per cent respectively. *See* Table.

Financial Statements

The Balance Sheet and the Income and Expenditure Account are appended hereto duly checked by our Auditors—Messrs. Timmins and Atwill. Branch accounts are not appended but all show a healthy financial status.

BALANCE SHEET AS AT 31st DECEMBER 1958

LIABILITIES	£ s. d.	£ s. d.	ASSETS	£ s. d.	£ s. d.
Sundry Creditors:			*Cash at Bank*	308 12 1	
Royal Aeronautical Society United Kingdom	71 7 9		*Cash in Hand*	5 11 2	
Subscriptions in Advance ..	59 16 9				314 3 3
D. S. Linett	1 5 6		*Investments*:		
General	5 5 0		Commonwealth Bonds at Cost Face Value £2,500	2497 10 0	
		137 15 0	M.W.S. and D. Debentures at Cost Face Value £500 ..	488 2 6	
Accumulated Funds:					2985 12 6
Balance as at 31st December 1958	3457 13 5		*Office Furniture*		10 0
Plus Surplus for the year ended 31st December 1958	12 14 10		*Library*		15 10 6
		3470 8 3	*Badge*		4 6
			Sundry Debtors:		
			Subscriptions in Arrears ..	252 16 6	
			Royal Aeronautical Society United Kingdom	1 6 0	
			Accrued Interest	38 0 0	
					292 2 6
		£3608 3 3			£3608 3 3

We have audited the books of accounts of the ROYAL AERONAUTICAL SOCIETY—AUSTRALIAN DIVISION for the twelve months ended 31st December 1958 and certify that the above Balance Sheet is in our opinion properly drawn up so as to exhibit a true and correct view of the Division's affairs according to the best of our information and the explanations given to us and as shown by the books of the Division. We have received all the information and explanations we have required.

Sydney—24th April 1959

TIMMINS & ATWILL
Chartered Accountants (Aust.)

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER 1958

	£ s. d.		£ s. d.	£ s. d.
To Audit Fees	5 5 0	By Subscriptions and Fees Due	1445 3 6	
„ Entertainment and General Expenses	76 2 4	*Less*: Due to U.K.	729 11 0	
„ Postage	32 11 3		715 12 6	
„ Rent	5 14 0	*Less*: Written Off	49 7 6	
„ Stationery	38 12 1			666 5 0
„ Royal Aeronautical Society:		„ Interest Received:		
Sydney Branch	165 0 0	Commonwealth Loans	112 10 0	
Melbourne Branch	169 10 0	Commonwealth Savings Bank	20 18 10	
Adelaide Branch	119 10 0			133 8 10
„ Special Grants:		„ Sundry Income:		
Sydney Branch—Air Show	100 0 0	Exchange		5 8
Adelaide Branch—Lecture	75 0 0			
	787 4 8			
„ *Transfer Surplus for Year to Accumulated Funds*	12 14 10			
	£799 19 6			£799 19 6

RECEIPTS AND PAYMENTS ACCOUNTS FOR THE YEAR ENDED 31st DECEMBER 1958

	£ s. d.	£ s. d.		£ s. d.	£ s. d.
To Cash in Bank		881 19 0	By Sundry Creditors:		
„ Members Subscriptions		1177 19 9	(Mrs. Ryan)		
„ Entrance and Transfer Fees		66 16 3	(W. Isbister)		2 13 4
„ Examination Fee		5 0 0	„ Royal Aeronautical Society:		
„ Sale of Publications		23 9 5	United Kingdom	702 12 8	
„ Institute of Aeronautical Sciences Subs.		12 7 6	Sydney Branch	162 10 0	
„ Interest:			Melbourne Branch	169 10 0	
Bonds	112 10 0		Adelaide Branch	119 10 0	
Bank	20 18 10				1154 2 8
		133 8 10	„ Stationery		38 12 1
„ Exchange		1 1 8	„ Stamps		32 11 3
„ Overpayment D. S. Linett		1 5 6	„ Rent		5 14 0
			„ Entertainment and General Expenses		76 2 4
			„ Special Donation—Sir Keith and Ross Smith Fund		75 0 0
			„ Special Donation — President's Tent		100 0 0
			„ Exchange		16 0
			„ Library		15 10 6
			„ M.W.S. and D.B. Purchase of Debentures		488 2 6
			„ Cash at Bank		308 12 1
			„ Cash in Hand		5 11 2
		£2303 7 11			£2303 7 11

THE LIBRARY

Reviews

SPACE FLIGHT. *Dr. Carsbie C. Adams. McGraw-Hill, New York. 373 pp. Illustrated. 50s. 6d.*

SPUTNIKS AND AFTER. *Karl Gilzin. Translated from the Russian by Pauline Rose and Dimitri Nesteroff. MacDonald, London. 285 pp. Illustrated. 21s.*

Here are two more semi-technical astronautical books, to join the ever-growing throng; one American, one Russian, both in the more serious category of popular works.

The first is written by the President of a high-sounding organisation of which this reviewer must plead total ignorance (The National Research and Development Corporation, of Atlanta, Georgia, U.S.A.). Three collaborators are also credited, two of them from the General Astronautics Corporation, which is a more modest concern than its title might suggest, and perhaps that is also true of this other, N.R.D.C.

However, the authors have obtained a foreword for their book from no less than Dr. Wernher von Braun, who says he is "certain that it will soon attain the stature of one of the few great classics on this fascinating and many-faceted subject." This seems rather excessive praise, for it shows little originality in its approach; its style struck this reader as somewhat pedestrian, even stodgy—lacking the insight and literary merit of similar works by Clarke or Ley, for example. However, it is thorough and generally sound, a good deal better than most of its competitors. A good feature is the extensive bibliography.

The book by Karl Gilzin has a special interest, of course, in the country of its origin, the current leader in the "Space Race." It would be too much to expect any revelations of modern Russian rocketry, though there are some interesting snippets of information about earlier days. Thus, in 1930, one Valentin Glushko is stated to have built a liquid-propellant rocket engine burning nitrogen tetroxide and toluene. On 15th May 1942, Capt. G. Bakhchivanji flew an aircraft with a liquid-propellant rocket engine designed by V. Bolkhovitinov.

The translation is good, and the party line not too intrusive, although it would seem that almost every idea originated in Russia, and: "Only after the people took the reins of government into their own hands did Tsiolkovsky have an opportunity to develop his ability to the utmost." In fairness, it should be mentioned that, in the field of rocketry, the U.S.S.R. can produce unchallengeable examples of true innovators, long before October 1957. Since then, it is unlikely that anyone would question their status.

All the points singled out for comment add to the interest of a book which would be good of its kind whatever the nationality of its author. Its similarity to comparable Western books is striking, and remains so, even after due allowance has been made for the derivative nature of much of the treatment. Young Russians, to whom this work is obviously largely addressed, are likely to respond with the same enthusiasm as their American and British counterparts, but perhaps with more encouragement from their government. It may be that the greatest influence of even the Western pioneers in astronautics will be felt in unintended quarters.—A. V. CLEAVER.

PROCEEDINGS OF THE 9th INTERNATIONAL ASTRONAUTICAL CONGRESS, AMSTERDAM, 1958. 2 Vols. *Springer, Vienna 1959. 970 pp. Illustrated. £17 13s. 6s.*

Seventy-four papers presented at the Amsterdam Astronautical Congress of 1958 are printed in these volumes, 53 being in English (though only three were from Britain), and the remainder in German, French, Italian or Russian. In a short review only a few of the individual papers can be mentioned; others equally worthy have to be ignored.

The largest group of papers, 30, is concerned with propulsion. The emphasis falls mainly on nuclear rockets, ion rockets and magneto-fluid-dynamics. One of the British authors, L. R. Shepherd, contributes an excellent paper on Electrical Propulsion Systems, while E. Stuhlinger provides a useful survey of Advanced Propulsion Systems. Theodore von Kármán offers an illuminating introduction to magneto-fluid-mechanics, as he would like to see the subject called, and L. G. Napolitano, in a longer and recondite paper, investigates the magneto-fluid-dynamics of two interacting streams. G. Partel describes the possible rôles of ram-jets in spaceflight, and the use of interstellar gas for space propulsion is considered by B. Karlovitz and B. Lewis.

Over a dozen papers are devoted to artificial satellites, including important contributions from V. I. Krassovsky, who gives the results of the scientific measurements made by instruments aboard Sputnik 3; from L. I. Sedov, who gives the fullest information yet published by the Russians on the orbits and dynamic behaviour of the first three Sputniks; and from W. von Braun, who describes the Explorer satellites. There are two admirable British papers, by R. H. Merson on the analysis of observations and T. R. Nonweiler on the re-entry of earth satellites. J. A. Van Allen gives a brief account of radiation measurements with Explorer 4, and A. R. Hibbs surveys the scientific results from the Explorers. There is also a paper by H. H. Koelle which has a magnificent bibliography of 860 references covering all aspects of satellites.

The remaining papers are varied in subject. F. L. Whipple describes a proposal for an astronomical telescope in orbit. S. F. Singer discusses the possible scientific measurements in cislunar space. F. Cap presents a method which he claims should lead to a complete solution of the famous *n*-body problem in astronomy. W. E. Moeckel, A. Miele and J. M. Kooy make comprehensive studies of, respectively, interplanetary trajectories, the variational theory of flight paths, and orbital calculations for deep space probes. Space medicine is discussed in five papers, and aerodynamics is not forgotten: F. G. Gravalos presents in a lengthy paper a solution for the supersonic flow about a blunt body of revolution.

Nearly all the papers are of a high scientific standard, and the volumes are essential to any library which covers astronautics. In earlier years the International Astronautical Congress may have attracted too many speculative contributions; but in face of the evidence from these volumes there is now no excuse for old-established scientific societies to look upon the Congresses with condescension, as they have tended to do in the past.

The volumes are well produced and printed, but their price is deplorably high, like that of the activities they seek to promote. (Apparently there is hope that the record of the 1959 Congress may be cheaper, however.) It is also rather sad that one of the first principles of astronautics—minimising the structure weight—is so flagrantly violated by these 5½ lb. volumes.—D. G. KING-HELE.

DICTIONARY OF GUIDED MISSILES AND SPACE FLIGHT. *Grayson Merrill (Editor). 5th volume in series Principles of Guided Missile Design. D. van Nostrand, Princeton. 688 pp. Illustrated. 131s. 6d.*

ROCKET ENCYCLOPEDIA. *J. W. Herrick and E. Burgess (Editors). Aero Publishers, Los Angeles. 607 pp. Photolithogravure. Illustrated. 69s.*

ROCKETRY AND SPACE EXPLORATION. *A. G. Haley. D. van Nostrand, Princeton. 334 pp. Illustrated. 51s.*

All three of these books (especially the first two) are of an encyclopaedic nature; they also have in common the qualities of being well-produced and well-illustrated, but not (unfortunately) of being entirely reliable.

Mr. Merrill's book is really an extraordinary hotch-potch. Under "A," one finds entries for A.10, A.B.M.A., Absolute Temperature, Areas (with formulae, *e.g.* for the surface area of a sphere; but there is no comparable entry for "Volumes"), As (Arsenic), Atlas and Autogyro. This wide-spreading of his net leaves little space for the entries more relevant to his subject-matter. "Hydrazine" gets only eight lines and "Rate gyro" only eleven; however, transistors and their circuitry admittedly receive more than nine *pages*, several times as much as rocket engines.

A number of spot-checks revealed few downright inaccuracies, but a great many entries which were the result of bad proof-reading, slip-shod phraseology, or the proverbial little knowledge which is such a dangerous thing. For example, the British range appears as "Alberporth," and "Atlas" has "a flared-base shirt." Hydrogen peroxide as a monopropellant has "a chamber pressure of 300 per sq. in. area, a 1800°F chamber temp., and a 715°F exit temp." The discussion of equations for rocket thrust is woolley, and includes the sentence "Wrong pressure refers either to the nozzle exit pressure or to the chamber pressure."

It is difficult to decide what class of reader would find this book useful, and one is surprised to see it appearing over the imprint of van Nostrand.

The Herrick/Burgess volume is more restricted in its scope, dealing almost entirely with rocket propulsion and related matters: engines, propellants, test equipment, and so on. It also succeeds in keeping to its point.

Some of the same criticisms of half-knowledge might be applied to it, as the following two quotations will show: "A compressible medium, such as a combustion gas . . . behaves as a compressible fluid only until the flow velocity reaches the velocity of sound." And: ". . . the editors recommend that the particular types be correctly identified by the appropriate terms: (1) thermonuclear rocket power plant, for those arrangements that utilize nuclear fission reaction and (2) nuclear rocket power plant, for those arrangements that utilize a nuclear fusion reaction." (This confusing suggestion is apparently *not* a misprint, because it is carried over into some cross-references.)

However, there is no doubt that a newcomer to rocket engineering would learn something from this work, and most of it would be basically correct; the illustrations are particularly good. This recommendation is repeated, without the reservations this reviewer thinks necessary, in a foreword by Dr. von Kármán.

In more humorous vein, Dr. von Kármán also contributes a foreword to the Haley book. He says that he queried some scientific points in it, whereupon: "'I claim,' said Andy, 'that being a lawyer, a radio allocations expert, and an astronaut, I have the good right to be mistaken in some other fields.'" Those who know Andy Haley will find this a typical remark, and his book is equally just the kind one would have expected him to produce. He is now the General Counsel of the International Astronautical Federation (of which he was President until after the 1959 I.A.F. Congress in London, when he was replaced by Prof. Sedov of the U.S.S.R.), and incidentally, was the first president of Aerojet.

His book outlines rocket principles and history, and then catalogues a great many rocket projects of the past twenty years, all the world's rocket and space-flight societies, and the story of the foundation and growth of the I.A.F. It contains a host of photographs and anecdotes of interesting astronautical events and people. As an appendix, there is a translation of a 1912 essay on space-flight by the great French pioneer, Robert Esnault-Pelterie. Indeed, it is a collectors' piece rather than a work for general consumption; a source-book for future historians. What a time they will have, however, sorting the wheat from the chaff, the sheep from the goats!

The style is epitomised by such passages as ". . . the immortal Cleator . . .," ". . . the world-famous and beloved writer, A. C. Clarke . . .," and: "The author of the book admires Prof. Low with the same sort of feeling he has for Sir Frank Whittle, Lovell Lawrence, and a number of others with whom he shared similar experiences."

The accuracy (oh, dear, here we go again!) is indicated by references to, *e.g.* "a 2,500 mile range ballistic missile known as Black Knight," or by statements such as: "A much greater volume of propellant can thus be made available in a liquid system, since it is not limited to what can be placed in the combustion chamber." Or by the caption of a photograph showing the present reviewer, seated on one of the fountains of Rome, with others, including one Millie MacFarlane, who appears in print as "Mrs. R. McMilland."—A. V. CLEAVER.

THE PHYSICAL METALLURGY OF MAGNESIUM AND ITS ALLOYS. *G. V. Raynor. Pergamon Press, London, 1959. 531 pp. Diagrams. 75s.*

Recent developments in the magnesium alloys, coupled with their more extensive utilisation in aircraft—particularly helicopters—have brought these materials into a quite special prominence. The importance of the weight factor in space technology also adds to their significance at the present time.

This book examines in considerable metallurgical detail the various alloy systems of magnesium, devoting roughly a chapter to its alloys with metals from each of the groups of the periodic table. This consideration is developed from a very good fundamental examination of the electronic structure and of the general alloying behaviour of magnesium, together with a review of knowledge on the deformation characteristics. The discussion is advanced and throughout the level of presentation is directed towards an enlightened, and fairly specialised, physical metallurgist. The mechanical properties are not given any very extensive treatment, but there is a useful short review of the main influences of alloying in this respect. Nuclear topics, such as the effects of irradiation, are not covered.

The book is certainly the most important presentation yet of magnesium metallurgy and will be a standard work

for those concerned with the subject in teaching and research, and would be a suitable text for more advanced students. It is well-organised and well-presented, but requires a well-informed metallurgical approach, and consequently mechanical engineers as such will hardly find it of great help in their considerations—fatigue, for example, is hardly mentioned. It will, however, be warmly acclaimed by the metallurgical readers for whom it is obviously intended.—A. J. KENNEDY.

THE SEVEN SKIES. *John Pudney. Putnam 1959. 320 pp. Illustrated. Index. 30s.*

The author has been careful to refer to this work as a study of the British Overseas Airways Corporation and its predecessors, and makes no claim to its being a history. Published on the fortieth anniversary of Great Britain's entry into the civil aviation field in 1919, *The Seven Skies* will provide a useful addition to any aviation library.

Written in light vein and often in an amusing style, it is really a potpourri of political facts, statistics, anecdotes, extracts from other works, and so on, all assembled in approximate chronological order and presented in non-technical language, the whole being punctuated occasionally with selected participants' reminiscences.

It must contain much of interest to those unfamiliar with the inside story of the build-up of passenger flying from its small beginnings in those early times, to the large fleets of aircraft which encircle the globe under B.O.A.C.'s escutcheon today. Beginning with pioneer flights from Hounslow Heath and Croydon, progress is described of the development and introduction of multi-engined air liners on the London-Paris route, expansion over Europe, survey flights to Africa and Australia, the flying boat era of Imperial Airways, culminating in the famous Empire Air Mail scheme, when all mail was carried without surcharge to many parts of the Empire.

The various amalgamations and the many changes in the political and management spheres, and the growing pains which took place throughout these times are interestingly chronicled, and several chapters are devoted to the fate at the outbreak of war of the existing routes and aircraft, and to describing alternative arrangements built up to provide the civil routes that proved so invaluable in the war effort.

Highlights of the book are accounts of Captain Wilcockson's first survey flight over the North Atlantic ocean and subsequent crossings; of the tremendous build-up of air traffic business in the post-war years, and the tragic story of the disasters to the Comet I's, and their eventual successful re-introduction in the form of Comet IV's as leaders in jet travel.

A somewhat inadequate description is given in the final chapters of B.O.A.C. as it is today, its flight personnel, its aircraft, routine and strange cargoes, and some of its passengers. The last chapter makes moving reading and is one of the best. This is historical in character and describes the travels of some members of the Royal Family, and of Neville Chamberlain and Winston Churchill.

The author is to be congratulated on compressing so much information into such a small volume. Its one fault, as he himself admits in the foreword, is that the work consequently suffers many omissions, and for this reason it will possibly prove disappointing reading to those who have grown up with the industry. One realises, of course, that some omissions are inevitable, but many names of well-known and well-liked personalities (administrators, pilots and engineers who have made valuable contributions to the development of civil aviation) are conspicuous by their absence. For instance, such names as Dennis Handover, Frank Saunders, and the late Eugene Esmonde, V.C., among others, immediately come to mind.

In fact, reading this book makes one realise the pressing need for a really comprehensive work on the same subject, giving the "behind the scenes" stories of all aspects of the growth of civil flying. It would be a pity that such an epic tale go untold and that the deeds of such men, and of more humble persons in the rank and file, should go unrecorded. In this respect one has in mind the many true stories of incidents, improvisations, sacrifices and adventures that can be related by the men who "kept them flying" through all sorts of circumstances in all parts of the world. Such a work should be more effectively illustrated than the one under review.—B. C. FROST.

HE FLEW BY MY SIDE. *Erwin Morzfeld. Translated by Mervyn Savill. Macdonald, London, 1959. 336 pp. 16s.*

No one who reads this book can fail to be struck by the extraordinary difference between the German fighting man and his English counterpart. The atmosphere of the German front-line squadron is quite unlike that of the British unit. The German relies upon codes of discipline demanding both arrogance and servility, depending upon personal status and seniority. The British unit seems to be so much more informal and friendly. It relies upon, and indeed it stands or falls by, its level of individual self-discipline. This book by a German torpedo-bomber pilot gives the reader an interesting glimpse of the German martial code under which no one seems to speak to a subordinate—he shouts. It is an awe-inspiring glimpse at a system which is abhorrent in its harshness. Yet this is a story of brave, determined men who made war on Allied shipping with little doubt in their minds about the eventual outcome of the Second World War and the inevitable collapse of the system with which they had grown up. No apologies are made in this book. No excuses. Yet, typically, there is an atmosphere of whitewash about it, despite the brutality towards weaker men. This, with the curious mixture of domination and tenderness towards weaker women, the German accepts as normal, in that strange fatalistic way he has.

It is well written and the translation is particularly well done, colloquial German being convincingly translated into colloquial English.—A.S.C.L.

HANDBOOK OF AUTOMATION, COMPUTATION AND CONTROL. Vol. 1. Control Fundamentals. *Edited by E. M. Grabbe, S. Ramo, D. E. Wooldridge. John Wiley, New York, 1958; Chapman and Hall, London. 974 pp. Index. 136s.*

Reviewing this book is rather like trying to review the *Encyclopaedia Britannica*. Running to well over 1000 pages, it is the first of three volumes which will, when complete, cover the entire field described in the title.

The present volume covers general mathematical methods, numerical analysis, operations research, information theory, and the general analysis of feedback systems. The analogy with an encyclopaedia is not far-fetched. The book consists of 26 chapters of varying lengths, contributed by 29 different authors. For each different topic the main results and techniques are presented in a condensed form suitable for reference, but in general the material is too tightly packed to allow a completely logical and self-contained development. For this reason the book cannot be recommended as a textbook for students.

The section on general mathematics contains much that has become standard in mathematics texts for engin-

eers. Matrices, complex variable theory, Laplace transforms, conformal mapping—all are there. In addition there are chapters on set theory, Boolean algebra, probability and statistics.

The chapter on operations research is largely concerned with linear programming and game theory, while the section on information theory covers data transmission, smoothing, and filtering. The final section on feedback systems, occupying almost half the book, covers general systems analysis, stability, transient and frequency responses, compensation methods, noise and random signal analysis, non-linear problems and sampled data systems.

In recent years the large and expensive compendium produced by "a group of experts" and giving wide coverage to a variety of subjects, has become increasingly popular. Like the present volume, these books are usually excellently written and produced, with copious references to more leisurely treatments of individual subjects. The contents vary, but there is often a depressing amount of duplication, especially of the purely mathematical topics. One cannot help wondering whether such volumes are really the most efficient way of storing and propagating scientific information.

The second volume will deal with digital computers and data processing problems and the third, with the engineering side of control systems and their components.—R. K. LIVESLEY.

EINFUHRING IN DIE THEORIE DER STROMUNGSMASCHINEN. *Albert Betz. Verlag G. Braun, Karlsruhe, 1959. 272 pp. Diagrams. DM 36. (In German.)*

Professor Betz broadly defines "flow-machines" as all those systems in which the relative motion of a fluid medium and a mechanical part or parts results in an exchange of forces. This obviously covers such diverse systems as the flow of fluids in conduits, turbo-machines, piston-pumps, and reaction-propulsion drives. These are so different in physical construction and in the detailed mode of operation that each has been productive of its own corpus of theory relating to both design and operation.

It has long been the wish of Professor Betz to formulate a consistent theory, starting from his initial definition, which would be demonstrably applicable to all these outwardly different systems. This book is the result of his endeavours.

The text is in four main sections. In the first the author presents the fundamental laws of the mechanics of fluids, explains his symbolism (which had to be devised to avoid ambiguity with the several existing systems) and examines the more important characteristics of fluid motion: pressure, adiabatic state, shear stress, cavitation, potential and circulation. The remaining three sections of the book show these characteristics in relation to the three main groups of flow-systems: conduits, cascades and turbo-machines (including rocket systems).

The section on conduits considers laminar and turbulent flow, inlet processes, variable cross-sections, curved channels, compression shocks, heat exchange, and variable-flow systems. Under cascades we find straight and circular systems, calculation of flow losses, blade-shape, entry and exit phenomena, effects of blade solidity, dimensions and shape.

The final section is appropriately the longest and covers the widest range of flow systems, too numerous to mention here but including pumps, blowers, steam-, water- and gas-turbines, rockets, propellers and windmills. Coverage for each is necessarily brief, outlining the principles of operation and indicating their relation to the fundamental theory. There are also subject and author indexes.

In his foreword Professor Betz points out that he and his academic colleagues have frequently in the past sought to demonstrate the underlying unity of theory for all these flow systems and this volume is a "distillation" of the individual and combined efforts. Although he writes with the authority of long experience and wide knowledge in his subject he rightly designates the book an "Introduction to the Theory . . ." since, to emphasise his theme, only the more important phenomena have been dealt with and even these in a very idealised and simplified form. The results are correspondingly approximate. It is also appropriate that a minimum of mathematics has been used, or is necessary, to state the argument. The work might well be used as a general textbook but should equally appeal to the specialist for its novel outlook.

Presentation and printing are of excellent quality and the sketches and diagrams clean and lucid.—F. A. BLAKE.

RAUMFAHRT—TECHNISCHE UBERWINDUNG DES KRIEGES. *Eugen Sänger. Rowohlt, Hamburg, 1959. 142 pp. D.M. 1.90. (In German.)*

The Rowohlt Taschenbücher are similar in presentation and purpose to the English Penguin Editions. They present, at a low price and in a cheap binding, reprints of modern and classical literature and also monographs on cultural and scientific subjects. These latter are included in the so-called "Encyklopädie" section which includes the present volume. Other contributions to this section include works by Einstein, Heisenberg, Oppenheimer, Nicol. The reader should not therefore expect a lightweight or frivolous text.

The topic—extra-terrestrial and space-flight—is of immediate importance in the context of current affairs; the author, Dr. Sänger, is a leading authority on his subject, a pioneer in the development of high-speed propulsion systems and first president of the International Astronautical Federation. His book can conveniently be considered in two aspects. Approximately the first half summarises the early history and current development of flight techniques and systems which have lead to the production of high-speed rockets, space satellites and the numerous scientific and military missiles in all their diversity. The basic presentation, explaining problems of materials, velocity, propulsion systems, is suitable for the layman or non-specialist scientist. An extensive table lists the reported high-speed aircraft and missiles of the major powers, with details of performance, dimensions and status of development. There are over 200 such items; but it is an interesting commentary on the state of the art that a similar list compiled today (two years later) contains over 500 entries. Unfortunately the list is marred by numerous misprints in the names of companies and missiles. Some of the technical data given are inevitably out-of-date.

The second and more significant half of this book gives Dr. Sänger's predictions on the effect of missile technology and astronautics on the development of world affairs. He deduces the effects on international military policy, travel, sociology and cultural development of nations and on the general development of science. Of particular interest is his belief (supported by very recent events) that the war of force must be superseded by a competition between major powers based on scientific prestige and economic expansion. It is in this sense of the title of the book that he sees astronautics as the conqueror of war.

The style of writing is not easy for the reader. The text is apparently summarised from a series of lectures and

first published in the journal "Aussenpolitik." This condensation probably explains the rather didactic quality of the statements and helps the logical nature of the argument, but at the expense of easy readability.

The layman or non-specialist will find this a valuable summary of the status of a most important technology. The specialist also should be aware of the non-technical implications of his science. He may not agree with the prognosis outlined by Dr. Sänger but if it stimulates his own thinking on the matter the book will have served its purpose.—F. A. BLAKE.

Additions to the Library

Annual Forecast of Trends and Requirements, 1959. Aerospace Industries Association. 49 pp. Graphs. The sixth annual publication produced by what was formerly Aircraft Industries Association. Part One—Engineering Forecast (pp. 1-32 divided into Environments, Systems, Materials, Testing); Part Two—Manufacturing Forecast (pp. 36-50 covering processes).

Cadmium—a Materials Survey. R. L. Mentch and A. M. Lansche. U.S. Dept. of the Interior. 1958. 43 pp. 2s. 8d. Information Circular 7881 of the Bureau of Mines, this is obtainable through H.M.S.O. One of a series being prepared to provide comprehensive fundamental data on strategic and critical materials.

Crimes on Board Aircraft. Bin Cheng. Stevens. 1959. A reprint of pages 177 to 207 of *Current Legal Problems*. A footnote on the first page says "Offences on board aircraft are being increasingly reported."

Desert Squadron. Victor Houart. Souvenir Press. 1959. 169 pp. Illustrated. 16s. *To be reviewed.*

Effect of Technological Progress on Education, The. Beryl Board. Inst. Prod. E. 1959. 141 pp. A classified bibliography from British sources covering 1945-1957. The references are listed in Universal Decimal Classification order from 370 to 378.6. A combined author-title index is provided.

Flight Evaluations of the Effect of Variable Spiral Damping in a JTB-26B Airplane. D. W. Rhoads. Cornell Aeronautical Laboratory. 83 pp. Illustrated. Report No. TB-1094-F-1. The aeroplane was modified to permit in-flight variation of spiral stability over a wide area. Data obtained show that spiral stability has a definite effect on the performance of the pilot-aeroplane system.

Fuels and Lubricants. Milosh Popovich and Carl Hering. Wiley (Chapman and Hall). 1959. 312 pp. 68s. A general survey of the field including rocket propellants and nuclear fuels. Each chapter has several references. Both authors are American professors.

Illustrated Review of Aviation, The. Host Wings' Convention Committee. 1959. A collection of illustrations celebrating the 9th Annual National Convention of the Royal Canadian Air Force and, in this case, the golden anniversary of powered flight in Canada.

Internal Stresses and Fatigue in Metals. G. M. Rassweiler and W. L. Grube (*Editors*). Elsevier. 1959. 451 pp. Illustrated. Figures. 72s. Proceedings of the Symposium on Internal Stresses and Fatigue in Metals, Detroit and Warren, Mich. 1958. *To be reviewed.*

Introduction to the Mechanics of the Solar System. R. Kurth. Pergamon. 1959. 174 pp. 42s. The author is in the Department of Astronomy at Manchester. The book introduces the reader to the fundamental methods of the astronomical part of celestial mechanics and it should be helpful in an undergraduate course. Vector notation has been used in the mathematics.

Jahrbuch der wissenschaftlichen Gesellschaft fur Luftfahrt E.V. 1958. H. Blenk (*Editor*). Braunschweig, Vieweg. 1959. 300 pp. Illustrated. *To be reviewed.*

Legal Aspects of Offences and Certain other Acts Occurring on Board Aircraft. G. Fitzgerald. Centro per lo Sviluppo dei Trasporti Aerei. Rome. 1959. 10 pp. A contribution by the Senior Legal Officer of I.C.A.O. to an increasing literature on the subject of Law and the Aeroplane.

Mechanism and Motion. K. H. Hunt. English Universities Press. 1959. 114 pp. Figures. 21s. A book on kinematics designed to present the subject so that the relationship between the analysis of linkage geometry and the practical design proposed is emphasised.

Of Men and Stars. Lockheed Aircraft Corporation. Illustrated. A history of the Lockheed company formed by binding together separate numbers which appeared from March 1957 to January 1958. Some of the personalities mentioned are well-known in this country.

Oil is Where They Find It. Edward Ward. Harrap. 1959. 255 pp. Illustrated. 18s. A general interest book about the discovery and processing of oil and the people in the industry.

Proceedings: IXth International Astronautical Congress. F. Hecht (*Editor*). Springer, Vienna. 1959. 2 Volumes. 506, 464 pp. Illustrated. £17 13s. 6d. *Reviewed in this issue.*

Sent Flying: the Autobiography of Bill Pegg. Bill Pegg. Macdonald. London. 1959. 236 pp. Illustrated. 21s. *To be reviewed.*

Servomechanisms and Regulating System Design. Vol. I Second Edition. Harold Chestnut and Robert W. Mayer. John Wiley, New York (Chapman and Hall). 1959. 680 pp. Diagrams. 94s. A second edition of Vol. I. first published in 1951, intended for engineers and engineering students who have not had previous training or experience in the field of closed-loop control systems. The revision has as its major additions a new chapter on the application of root-locus to the analysis and synthesis of control system design and a chapter on the use of an analogue computer for the solution of control systems problems. Nomenclature has been revised to accord with present practice and new problems have been added.

Similitude of Hypersonic Flows Over Thin and Slender Bodies—an Extension to Real Gases. H. K. Cheng. Cornell Aeronautical Laboratory. 1958. 13 pp. Charts. Report No. AD-1052-A-6. Similitude in the hypersonic inviscid flow fields over thin or slender bodies is examined, wherein the restriction to ideal gas with constant specific heats is removed. Examples of correlation are given for flows of real gases over wedges.

Space Technology. Howard Seifert (*Editor*). Chapman and Hall. London. 1959. Sectional pagination. Illustrated. 180s. *To be reviewed.*

Theoretical Elasticity and Plasticity for Engineers. D. E. R. Godfrey. Thames and Hudson. London. 1959. 311 pp. Diagrams. 42s. *To be reviewed.*

Theory of Elasticity. L. D. Landau and E. M. Lifshitz. Pergamon. London. 1959. 134 pp. 40s. *To be reviewed.*

Use of Perforated Walls for Shock Cancellation at Supersonic Speeds. H. Ramm and M. Jones. U.S.A.F., A.R.D.C. 97 pp. Illustrated. Report AEDC-TR-59-15 of the Arnold Engineering Development Center. Tests with two- and three-dimensional models showed the feasibility of satisfactory shock cancellation for at least moderate model blockage values.

Papers presented at the S.A.E. Aeronautical Meeting

(Los Angeles, 5th-9th October 1959)

Paper No.

97T GAM-77 ground support equipment. E. B. Price.
97U Thor ground support equipment—an engineering challenge. R. Stoner and F. C. Allgreen.
97V Procedure for optimising ground support equipment as applied to Falcon missiles. B. A. McDonald.
98T Evaluation of ablation materials for high temperature application. M. A. Schwartz *et al.*
98U Development of new extruding techniques for pure beryllium and high temperature steel. L. M. Christensen.
98V Application of materials to high temperature service in rocket engines. R. P. Frohnberg.
99T Structural foil for hot parts. M. J. Breitenbach.
99U Optimum joint design for high-temperature honeycomb panels. F. J. Filippi and B. Levenetz.
99V A mass produced, all welded, high temperature sandwich. J. W. Scheuch.
100T Design procedure for vibration isolation on non-rigid supporting structures. S. Rubin.
100U Material and structural damping for vibration control. B. J. Lazan.
100V Selection of methods and instruments for vibration and shock testing. T. P. Rona.
100W Methods of estimation in vibration and shock problems. C. T. Molloy.
100X Considerations in the design of shock and vibration tests. I. Vigness.
100Y Increased reliability of aviation and missile electronics by use of damped structures. J. E. Ruzicka.
100Z Investigation of a resonance-free vibration isolation system. G. H. Klein.
101T Progress report—S.A.E. sub-committee on reliability. F. D. Applegate.
101U Design for reliability. B. B. Richardson.
101V Reliability design criteria. J. M. Brown *et al.*
102T A 600°F hydromechanical constant speed drive. E. W. Kruger and S. S. Baits.
102U 600°F constant speed drives—mechanical traction type. C. D. Flanigen.
102V A 600°F airborne electrical system. J. J. Pierro.
103T Turbine fuel thermal stability—C.F.R. Coker and Flight Evaluations. J. D. Rogers.
103V Future applications of ducted fan powerplants. N. Burgess and A. P. Fioretti.
104U Applications of current materials to hot airframe design. M. B. Dunn *et al.*
104V High-quality critical structural 17-4PH investment castings. K. E. Kuschell and W. R. Roser.
105T Analytical techniques for the prediction of the temperature distribution of a cold plate equipment conditioning system. T. S. Newby and G. M. Beller.
105U Flight vehicle power. R. A. Jones and J. S. Keeler.
105V Development of high-temperature thermocouple materials. R. C. Lever.
106U Basic structures for air launched missiles. R. H. Loughran and L. A. Nelson.
106V Properties of asbestos reinforced laminates at elevated temperatures. N. E. Wahl.
107T Radiation effects studies for the development of radiation-resistant aircraft subsystems. J. J. Tierney.
107V Convair 880 fuel system test program. J. McCafferty and G. Karel.
108T Development and application of fatigue analysis to aircraft fasteners. J. L. Chinn.
108U Convair's B-58 cyclic fatigue certification program. C. D. Little.
108W Prediction of aircraft wing gust fatigue damage by means of power spectral analysis and constant life curves. R. H. Games.
109T A year of jet operation experience at New York International Airport. T. M. Sullivan.
109U Ground support and handling of jet aircraft. G. W. McKenzie.
109V A systems approach to the support of jet aircraft. C. J. Breitwieser.
110T The Boeing 707 in service. R. M. Morgan.
110U Development and operation of the Lockheed Electra. R. W. Partridge *et al.*
110V The first year of the jet age—reflections. F. W. Kolk.
111T Preliminary design considerations for the structure of a trisonic transport. M. G. Childers.
111U Automatic navigation for supersonic transports. R. F. Miller.
111V Doppler-inertial navigation for high performance aircraft. L. S. Reel.
112T The affect of properties of materials for 1000°F motors on design voltage for optimum specific output. E. A. Linke.
112U The development and testing of high temperature bearings. R. T. Westmoreland and P. J. Hanifin.

Reports

AERODYNAMICS

BOUNDARY LAYER—*see also* PERFORMANCE
THERMO-AERODYNAMICS
WINGS AND AEROFOILS
TESTING AND INSTRUMENTS

Transition from a turbulent to a laminar boundary layer. A. A. Sergienko and V. K. Gretsov. R.A.E. Trans. 827. *Aug.* 1959.—(1.1.2.4).

Solutions of the laminar compressible boundary layer equations with transpiration which are applicable to the stagnation regions of axisymmetric blunt bodies. J. T. Howe and W. A. Mersman. N.A.S.A. T.N. D-12. Aug. 1959.
Solutions of the laminar compressible boundary layer equations in the Brown and Donoughe form are obtained for Euler number 1/3 and Prandtl number at the wall equal to 0·7. Fifteen solutions are presented for various wall temperature levels and transpiration rates. The solutions are applicable to the stagnation region of axisymmetric bodies by means of the Mangler transformation.—(1.1.1.4×1.9.1).

Low-speed wind tunnel investigation of blowing boundary layer control on leading- and trailing-edge flaps of a full-scale, low-aspect-ratio, 42° swept-wing airplane configuration. R. L. Maki and D. J. Guilianetti. N.A.S.A. T.N. D-16. Aug. 1959.
Single- and double-droop leading edge flaps and trailing edge flaps with blowing BLC were tested for an angle of attack range through stall. Lift, drag, pitching moment, and rolling moment data were recorded for leading edge flap deflections to 60° and trailing edge flap deflections of 40° and 55°. Effects of plugs in the trailing edge nozzle on lift and roll control with flaps differentially deflected as ailerons are presented.—(1.1.6.1×1.3.4×1.3.7×1.8.1.2×1.8.2.2).

Analysis of computed flow parameters for a set of sudden stalls in low-speed two-dimensional flow. W. T. Evans and K. W. Mort. N.A.S.A. T.N. D-85. Aug. 1959.—(1.1.1.1×1.1.3.1×1.10.0.1).

COMPRESSIBLE FLOW—*see also* INTERNAL FLOW
LOADS
WINGS AND AEROFOILS
AEROELASTICITY
THERMODYNAMICS

Calculation of supersonic flow past bodies supporting shock waves shaped like elliptic cones. B. R. Briggs. N.A.S.A. T.N. D-24. Aug. 1959.
Numerical solutions are presented for supersonic perfect gas flow. The full inviscid equations are used and conditions at the shock wave are prescribed. Body shapes and surface pressure distributions are obtained.—(1.2.3.1×1.4.1×22.1).

CONTROLS—*see also* BOUNDARY LAYER
STABILITY AND CONTROL
WINGS AND AEROFOILS
AEROELASTICITY

A limited flight and wind tunnel investigation of paddle spoilers as lateral controls. R. G. Mungall et al. *N.A.S.A. T.N. D-32. Sept.* 1959.
The flight investigation was made with a sweptback-wing fighter aeroplane and the wind tunnel investigation was made on a semispan wing model in the Langley 300 m.p.h. 7×10 ft. tunnel. Results are presented on the rolling effectiveness and the hinge moment characteristics of the paddle spoilers at various subsonic speeds.—(1.3.8×1.8.1.2).

FLUID DYNAMICS—*see also* COMPRESSIBLE FLOW

On series expansions in magnetic Reynolds number. V. J. Rossow. N.A.S.A. T.N. D-10. Aug. 1959.
The method of finding magnetohydrodynamic flow solutions by expansion of the flow parameters in a power series of the magnetic Reynolds number is discussed. The characteristics of the solutions are illustrated by several examples.—(1.4.4×17.1).

Les autoplissements et les auto-enroulements dynamiques dans les fluides a viscosité. F-J. Bourrieres. Pubs. Sc. et Tech. N.T. 83. 1959. (*In French.*)
Continuous movement in a viscous fluid is studied using the intrinsic equations. After considering two dimensional disturbances (jets, wakes, flow past wedges) a simple and rigorous analysis of infinite vortices is provided. The idea of fluid motion as consisting of fluid layers of constant velocity is expanded.—(1.4).

Boundary value problems in lifting surface theory. E. van Spiegel. Tech. Report W 1. *NLL Reports & Trans. Vol. XXII.* 1959.—(1.4.1).

INTERNAL FLOW—*see also* TESTING AND INSTRUMENTS
POWER PLANTS

Systematic two-dimensional cascade tests of N.A.C.A. 65-series compressor blades at low speeds. J. C. Emery et al. *N.A.C.A. Report* 1368. 1958.
A two-dimensional, low speed, porous wall cascade tunnel investigation has been conducted to establish the performance of the N.A.C.A. 65-series compressor blade sections over the useful range of inlet angle, solidity, and section camber. Design points for optimum high speed operation are presented. The loading limitation is determined for some conditions. Trends of section operating range with increasing section camber are determined for the four inlet angles tested.—(1.5.4.2×1.5.2.1).

Design of axisymmetric exhaust nozzles by method of characteristics incorporating a variable isentropic exponent. E. C. Guentert and H. E. Neumann. N.A.S.A. Report R-33. Sept. 1959.—(1.5.1×1.2.3.1×27.3.1×34.1).

LOADS—*see also* WINGS AND AEROFOILS
STRUCTURES—LOADS

Transonic aerodynamic characteristics of several bodies having elliptical cross sections and various plan forms. R. A. Taylor. N.A.S.A. T.N. D-14. Aug. 1959.
Measured force characteristics are presented for bodies with elliptical cross sections whose major to minor axis ratios are 3 and 4 and whose lengths are 58, 72, and 85 per cent of the closure length. The bodies were tested through an angle of attack range from −2° to +12° and Mach number range from 0·40 to 1·20.—(1.6.1×1.2.2×1.8.0).

Summary of VGH and V-G data obtained from piston-engine transport airplanes from 1947 *to* 1958. *W. G. Walker and M. R. Copp. N.A.S.A. T.N. D-29. Sept.* 1959.
Data obtained with VGH and V-G recorders from piston engined aeroplanes used in feeder, short haul, and long haul transport operations during 1947 to 1958 have been analysed and compared to determine the variations in the frequency of occurrence of gust velocities, gust and manoeuvre accelerations, and the associated air speeds. Estimates of the overall gust and gust acceleration histories for extended operations were obtained in several cases by combining the V-G and VGH data obtained from the same operations.—(1.6.2×5.1×33.1.1×1.6.3).

PERFORMANCE—*see also* WINGS AND AEROFOILS
MISSILES

Considerations of some aerodynamic characteristics during take-off and landing of jet airplanes. J. M. Riebe. N.A.S.A. T.N. D-19. Sept. 1959.
These considerations are limited to lift drag relations and do not include such possible related factors as noise, heating, foreign-matter ingestion, or ability to obtain thrust reversal.—(1.7×1.10.0.2×1.1.6.1×1.8.0.1).

Approximate solutions to optimum climbing trajectory for a rocket-powered aircraft. A. Miele and J. O. Cappellari. N.A.S.A. T.N. D-150. Sept. 1959.—(1.7×27.3.1).

Approximate solutions to optimum flight trajectories for a turbojet-powered aircraft. A. Miele and J. O. Cappellari. N.A.S.A. T.N. D-152. Sept. 1959.
Problems involving either time or fuel consumed or horizontal distance flown by the aircraft are considered and paths extremising any of the three quantities, for the case where each of the other two is either free of choice or prescribed, are investigated. Numerical examples are presented for the minimum time problem and the effect of wing loading on the solutions is investigated.—(1.7×27.1.1).

STABILITY AND CONTROL—*see also* BOUNDARY LAYER
CONTROLS
LOADS
PERFORMANCE
WINGS AND AEROFOILS

*Preliminary note on the effect of inertia cross-coupling on aircraft response in rolling manoeuvres. W. J. G. Pinsker. C.P.*435. 1959.—(1.8.11).

The inertial effects of springs in resonance and free oscillation experiments to determine damping. M. D. Frost. A.R.L. Report A/111. *Jan.* 1959.
Analyses are given of the effect of spring mass on the results of resonance and free oscillation experiments. In both cases an expression is derived for the damping coefficient and criteria are given for the reduction of each to a simple form.—(1.8.1.2×22.2).

Effectiveness of an all-movable horizontal tail on an unswept-wing and body combination for Mach numbers from 0·60 *to* 1·40. *L. S. Stivers. N.A.S.A. T.N. D-13. Aug.* 1959.
Lift, drag, and pitching moment coefficients were determined. The Reynolds number was 1·5 million. The effective downwash characteristics at the horizontal tail were evaluated and are presented. Calculated lift and pitching moment curve slopes and effectiveness of the horizontal tail were determined.—(1.8.2.2×1.3.2.2).

The analysis and design of continuous and sampled-data feedback control systems with a saturation type nonlinearity. S. F. Schmidt. N.A.S.A. T.N. D-20. Aug. 1959.
Methods are derived for designing and analysing feedback control systems in which a saturation type nonlinearity occurs on the input to the plant. The methods are used to determine nonlinear compensation functions to compensate for the undesirable effects of saturation. Several aircraft auto-pilot examples where the control surface rate is limited are given.—(1.8.0.1×4.2.3).

Moving-cockpit simulator investigation of the minimum tolerable longitudinal maneuvering stability. B. P. Brown and H. I. Johnson. N.A.S.A. T.N. D-26. Sept. 1959.
Tests have been made on a moving cockpit simulator (normal acceleration and pitch simulator) to determine the minimum tolerable manoeuvring stability. Quantitative measurements of the effects of force gradient, position gradient, aircraft damping, and pitching motion cues, with respect to a formation flying task, are presented.—(1.8.2.1).

Some data on elevator damping and stiffness derivatives on a delta wing aircraft model at supersonic speeds. K. J. Orlik-Ruckemann. N.R.C. Report LR-250. June 1959.
Elevator hinge moment derivatives at supersonic speeds were determined on a half model of a delta wing aircraft, using an apparatus for free oscillation tests on small surfaces. The results obtained have been compared with results of theoretical calculations.—(1.8.2.2×1.3.2×1.12.1.3×2).

Low-subsonic measurements of the static and oscillatory lateral stability derivatives of a sweptback-wing airplane configuration at angles of attack from −10° to 90°. D. E. Hewes. N.A.S.A. Memo 5-20-59L. T.I.L. 6506. *June* 1959.
The dynamic force tests consisted of both linear- and rotary-oscillation tests and were conducted at values of the reduced-frequency parameter of 0·10, 0·15, and 0·20.—(1.8.1.2).

THERMO-AERODYNAMICS—*see also* BOUNDARY LAYER
TESTING AND INSTRUMENTS
DESIGN AND CONSTRUCTION
MISSILES

Laminar skin-friction and heat-transfer parameters for a flat plate at hypersonic speeds in terms of free-stream flow properties. J. F. Schmidt. N.A.S.A. T.N. D-8. Sept. 1959.—(1.9.1×1.1.1.4).

Shielding stagnation surfaces of finite catalytic activity by air injection in hypersonic flight. P. M. Chung. N.A.S.A. T.N. D-27. Aug. 1959.
A study was made on the effect of air injection in shielding stagnation surfaces, which have various finite catalytic activities, from aerodynamic heating in hypersonic flight. Only the case of chemically frozen boundary layer was considered. A set of closed-form solutions was obtained which enables one to calculate heat transfer rate when the blowing rate and the catalytic characteristics of the surface material are given.—(1.9.1×1.1.1.4).

Effects of chemical dissociation and molecular vibrations on steady one-dimensional flow. S. P. Heims. N.A.S.A. T.N. D-87. Aug. 1959.
Equations are derived from which the one-dimensional flow of gases simultaneously subject to dissociation and vibration can be computed. The cases considered include both frozen and equilibrium flows and flows where either dissociation or vibration is frozen while the other is in equilibrium. Flows in which the chemical reaction and vibrations are not in equilibrium are also studied.—(1.9×32×22×34.4).

On the temperature distribution behind cylinders in a flow. J. Ackeret. N.A.S.A. T.T. F-2. Aug. 1959.
A simple theoretical explanation of the aerodynamic cooling often found near the base and in the wake of bluff bodies is presented. The case of two-dimensional flow past a cylinder is examined in detail. The calculated temperature distribution around a cylinder assuming the flow incompressible is compared with a distribution found experimentally at $M=0{\cdot}35$.—(1.9).

WINGS AND AEROFOILS—*see also* BOUNDARY LAYER
PERFORMANCE

*Wind tunnel investigation of aerodynamic hysteresis on the Avro 707A. P. B. Atkins and D. G. Hurley. A.R.L. Note A.*172. *March* 1959.—(1.10.2.2×1.1.4.1).

Measured and predicted section wave drag coefficients at a Mach number of 1·6 for a delta wing with two airfoil sections. F. C. Grant. N.A.S.A. T.N. D-11. Sept. 1959.
The sweep angle was 60° and the thickness ratio was 6 per cent on both models. One wing had an N.A.C.A. 65A006 section and the other had a section which produced a cross-sectional area distribution on the model identical to that of a Sears-Haack optimum body of revolution for given length and volume. Values of section drag computed by linear theory are compared with the experimental values.—(1.10.0.2×1.6.1).

Wind tunnel investigation of effect of ratio of wing chord to propeller diameter with addition of slats on the aerodynamic characteristics of tilt-wing VTOL configurations in the transition speed range. R. T. Taylor. N.A.S.A. T.N. D-17. Sept. 1959.—(1.10.2.2×29.9×1.7×1.8.2.2×1.3.4).

Experimental investigation at transonic speeds of pressure distributions over wedge and circular-arc airfoil sections and evaluation of perforated-wall interference. E. D. Knechtel. N.A.S.A. T.N. D-15. Aug. 1959.—(1.10.2.2×1.2.2×1.12.1.2).

Drag minimization for wings and bodies in supersonic flow. M. A. Heaslet and F. B. Fuller. N.A.C.A. Report 1385. 1958.
Minimisation of inviscid fluid drag is studied for wings subject to constraints on lift, pitching moment, base area, or volume. A simple result for given base area, encompassing a large class of wings and bodies, is found.—(1.10.1.2×1.2.3.1).

Pressure distribution and force measurements on a VTOL tilting wing-propeller model. J. A. Dunsby et al. *N.R.C. Report LR-252. June* 1959.
Tabulated results of pressure and force measurements on a half wing model of a twin-engined tilt-wing VTOL configuration over a range of thrust coefficient for a limited range of incidence are presented—(1.10.2.2×29.9).

HELICOPTER AERODYNAMICS

A dynamic model investigation of the effect of a sharp-edge vertical gust on blade periodic flapping angles and bending moments of a two-blade rotor. J. L. McCarty et al. *N.A.S.A. T.N. D-31. Sept.* 1959.
A two-blade rotor was subjected to sharp-edged vertical gusts while being operated at various forward velocities to study the effect of the gusts on the blade periodic bending moments and flapping angles. Variables studied include gust velocity, collective pitch angle, flapping hinge offset, and tip-speed ratio.—(1.11.3×4.4.1×33.1.2×33.2.4.1.2).

TESTING AND INSTRUMENTS—*see also* STABILITY AND CONTROL
WINGS AND AEROFOILS

*Microwave technique applied to the investigation of ionised gases in shock tubes. D. L. Schultz. C.P.*436. 1959.
Some techniques which use the radiation and transmission of millimetre and centimetre wavelength electromagnetic waves are reviewed. Such techniques may be of use in studies of electron density and ionisation-recombination phenomena which are at present of interest in hypersonic flow.—(1.12×32.2×34.1).

A method for simulating the atmospheric entry of long-range ballistic missiles. A. J. Eggers. N.A.C.A. Report 1378. 1958.
It is demonstrated with the aid of similitude arguments that a model fired from a hypervelocity gun upstream through a special supersonic nozzle should undergo motion and experience aerodynamic heating and resulting thermal stresses like those encountered by a long-range ballistic missile entering the earth's atmosphere. This combination of hypervelocity gun and supersonic nozzle is therefore termed an Atmosphere Entry Simulator.—(1.12.1.3×1.9.1).

Characteristics of the Langley 8-foot transonic tunnel with slotted test section. R. H. Wright et al. *N.A.C.A. Report* 1389. 1958.
The design and operational characteristics of the Langley 8 ft. transonic tunnel are presented for Mach numbers up to approximately 1·14. The effects of slot shape and of a nonlifting model on the flow characteristics are illustrated and the surveys and calibration of the flow in the test section are described. Boundary-interference effects at low supersonic Mach numbers are discussed and experimental data concerning model lengths for interference-free supersonic testing and locations of detached shock waves ahead of axially symmetric bodies are presented.—(1.12.1.2×1.5.1.4).

Two techniques for detecting boundary layer transition in flight at supersonic speeds and at altitudes above 20,000 *feet. J. G. McTigue* et al. *N.A.S.A. T.N. D-18. Aug.* 1959.
The location of transition was measured on a supersonic fighter-type aeroplane by resistance-thermometer and sublimation techniques. Application of these techniques required the use of only the external surface without disturbing the internal structure. Agreement between the two methods is discussed. Also presented are possible extensions of the programme to higher Mach numbers.—(1.12.2×13×1.1.2.4).

A small wind tunnel for investigating the characteristics of a wing in a finite jet including results of a model with a suction flap. D. J. Marsden. N.R.C. Report LR-255. May 1959.
An open return blower tunnel producing a 0·667 ft. diameter free jet is described. This jet is considered to be a simplified

model of a fully contracted propeller slipstream which can be used to investigate the interactions of propeller slipstreams and wings with flaps. Measurements were made using a wing flap model having a 30 per cent chord flap with suction boundary layer control. Results obtained with this facility were comparable with results of other similar investigations made with wing flap models operating in a propeller slipstream.—(1.12.1.1×1.3.4).

AEROELASTICITY

See also AERODYNAMICS—STABILITY AND CONTROL

*Flutter of an untapered wing allowing for thermal effects. E. G. Broadbent. C.P.*442. 1959.
The flutter problem of a thin rectangular solid steel wing of aspect ratio 3 is considered with allowance for reduction in stiffnesses due to thermal effects.—(?).

Investigation of methods for computing flutter characteristics of supersonic delta wings and comparison with experimental data. C. H. Wilts. N.A.S.A. T.N. D-5. Aug. 1959.
A study was made of the flutter characteristics of two delta wings using an electric-analogue computer. Comparison is made of the structural characteristics with experimental values. Using strip theory and the box method to represent the aerodynamics, the analogue flutter characteristics were also compared with experimental values. A partial check of the analogue procedures is furnished by a flutter analysis on a digital computer.—(2).

On the aileron buzz in the transonic flow. H. Saito. Aero. Res. Inst. Tokyo. Report 346. *July* 1959.—(2×1.2.2.2×1.3.1.1).

AIRCRAFT

See FATIGUE

DESIGN AND CONSTRUCTION

See also AERODYNAMICS—STABILITY AND CONTROL
HELICOPTER AERODYNAMICS
AIRCRAFT OPERATION
AIRPORTS

Design processes for high speed flight. B. O. Heath. AGARD Report 215. *Oct.* 1958.
Earlier supersonic design problems are reviewed, conclusions are drawn in the light of which the newer problems of heating are examined. Current experience of temperature as a design parameter is discussed, especially in relation to flight factors, and it is concluded that the solutions to heating problems themselves will not be entirely without relief. New materials, and methods of presenting their properties at high temperature, are also discussed.—(4×1.9×21).

AIRCRAFT OPERATION

See also AERODYNAMICS—LOADS
POWER PLANTS

Jet-engine exhaust noise from slot nozzles. W. D. Coles. N.A.S.A. T.N. D-60. Sept. 1959.
Acoustic characteristics of slot nozzles were investigated using a full scale turbo-jet engine installed in an airframe. Directional distribution of sound-pressure level, frequency distribution, overall sound power, and power-spectrum level are compared with circular-nozzle noise characteristics.—(5.6×27.1).

Some tests on Befab 'Safeland' safety barriers. G. Salis. AGARD Report 228. *Oct.* 1958.
Results obtained during tests carried out on a device known as the Befab "Safeland" Barrier, the object of which is to arrest jet aircraft in short distances, are described. The results show that it is possible to arrest jet aircraft in landing or take-off, in relatively short distances and with an almost constant longitudinal deceleration of about 1*g*.—(5.3×4.2.2.3×6.5).

Etude de l'emploi du parachute-frein a l'atterrissage. J. Gremont. AGARD Report 229. *Oct.* 1958.
Facts about the parachute method of braking are reviewed. The first part discusses the problem experimentally, the second develops the theoretical aspects and the third contains observations on the various results of its use in service conditions.—(5).

Ground deceleration and stopping of large aircraft. J. A. Zalovcik. AGARD Report 231. *Oct.* 1958.
The effect of various factors on the ground deceleration and stopping distance of aircraft is discussed. Sources of deceleration such as wheel braking, aeroplane drag, aerodynamic brakes, parachutes, reversed turbo-jet thrust, and reversed thrust of turbo-propeller engines are considered. The effect of tyre friction, wheel load, and brake capacity on wheel braking and the effect on stopping distance of aeroplane handling techniques that involve the use of elevators, flaps, spoilers, and nose-high attitude angles are covered in some detail. A mathematical analysis of some of the factors affecting deceleration and stopping distance is included.—(5).

AIRPORTS

See also AIRCRAFT OPERATION

Measurements and power spectra of runway roughness of an airport (Airport 5). *AGARD RM* 5. *Aug.* 1959.—(6.1×33.1.2×4.2.2.3).

Measurements and power spectra of runway roughness of an airport (Airport 6). *AGARD RM* 6. *Sept.* 1959.—(6.1×33.1.2×4.2.2.3).

EXTRA-ATMOSPHERIC TECHNOLOGY

The motion of an artificial earth satellite relative to its centre of mass. V. V. Beletskii. R.A.E. Lib. Trans. 824. *June* 1959.
The motion of an artificial earth satellite about its centre of mass under the action of aerodynamic and gravitational disturbances has been analysed, taking into account the influence of the regression of the orbit due to the earth's oblateness.—(8.1).

The universe discloses its secrets: investigation of cosmic space by means of rockets and satellites. (Pravda, 15*th July). Translated by J. W. Palmer. R.A.E. Lib. Trans.* 834. *Aug.* 1959.
Translation of an article from *Pravda* comprising: investigation of radiation near the earth and in cosmic space; study of the upper atmosphere; investigation of interplanetary gas; study of the earth's magnetic field; micrometeors; biological investigations; basic trends in the development of cosmic flight.—(8.1×25).

ELECTRONICS

See also MECHANICAL ENGINEERING

A linear selection memory with transistor driving circuits. B. Jiewertz. On the temperature margins of a transistor-driven coincident current ferrite core memory. J-R. Törnquist. SAAB Tech. Report TR 4. 1959.—(11×18).

FLIGHT TESTING

See AERODYNAMICS—TESTING AND INSTRUMENTS

FUELS AND LUBRICANTS

See THERMODYNAMICS

HYDRODYNAMICS

See AERODYNAMICS—FLUID DYNAMICS
POWER PLANTS

INSTRUMENTS AND EQUIPMENT

See ELECTRONICS

MATERIALS

See also DESIGN AND CONSTRUCTION
STRUCTURES—THEORY AND ANALYSIS

Vacuum-induction, vacuum-arc, and air-induction melting of a complex heat-resistant alloy. R. F. Decker et al. *N.A.S.A. T.N. D-6. Aug.* 1959.
The relative hot-workability and creep rupture properties at 1,600°F of a complex 55Ni-20Cr-15Co-4Mo-3Ti-3Al alloy were evaluated for vacuum-induction, vacuum-arc, and air induction melting. A limited study of the role of oxygen and nitrogen and the structural effects in the alloy associated with the melting process was carried out.—(21.2.2).

Effects of creep stress on particulate aluminum-copper alloys. E. E. Underwood and G. K. Manning. N.A.S.A. T.N. D-109. Sept. 1959.
Particle dissolution, grain growth, and precipitation were studied under creep conditions in over-aged alloys of aluminium with 1, 2, 3, and 4 per cent copper. Particle dissolution, with or without stress, is described by the same kinetic equation that applies to tempering and other phase transformations.—(21.2.2).

Relationship of polymer structure to thermal deterioration of adhesive bonds in metal joints. J. M. Black and R. F. Blomquist. N.A.S.A. T.N. D-108. Aug. 1959.
A study was made of adhesives used to bond aluminium and stainless steel and of the resistance of these adhesives to thermal deterioration when aged for 100 hours at temperatures up to 600° F.—(21.2.1 × 21.2.2 × 33.2.4.13).

Influence de la température sur le comportement cristallin du fer soumis a des déformations par torsion alternée. J. de Fouquet. Pub. Sc. et Tech. N.T. 81. 1959.—(21.2.1 × 31.2.2.2.1).

MATHEMATICS

See also AERODYNAMICS—COMPRESSIBLE FLOW
STABILITY AND CONTROL
THERMO-AERODYNAMICS

Tables of the Bessel-Kelvin functions Ber, Bei, Ker, Kei and their derivatives for the argument range 0(0·01)107·50. *H. H. Lowell. N.A.S.A. TR R-32.* 1959.—(22.1).

L'interprétation des mesures par la clause de régularité. Applications philosophie de l'expérience. P. Vernotte. Pubs. Sc. et Tech. N.T. 82. 1959.—(22.1).

MECHANICAL ENGINEERING

A servo-multiplier for the A.R.L. electronic analogue computer. J. A. Phillips and T. J. Struys. A.R.L. Report 1.22. *Oct.* 1958.
The performance of the servo-multiplier is specified. Some criteria for the choice of a low power servo-motor are developed. Expressions for optimum gearbox ratios are derived and a simple gearbox is designed and described. The transfer function of the motor and load is obtained and methods of network synthesis are applied in the design of a feedback system satisfying the specification.—(23.3 × 11).

Influence of shaft deflection and surface roughness on load-carrying capacity of plain journal bearings. F. H. Raven and R. L. Wehe. N.A.S.A. T.N. D-4. Aug. 1959.
The load capacity of a full journal bearing with flexible shaft is evaluated mathematically by using the criterion of first local metallic contact. A method for determining the optimum length/diameter ratio of a bearing for maximum load capacity, based both on shaft deflection and bearing surface roughness, is given.—(23.1).

MISSILES

See also EXTRA-ATMOSPHERIC TECHNOLOGY

A comparative analysis of the performance of long-range hypervelocity vehicles. A. J. Eggers et al. *N.A.C.A. Report* 1382. 1958.
A simplified analysis is made of the motion and aerodynamic heating of long range ballistic-, skip-, and glide-type vehicles. The paper concludes with some brief considerations of the design of manned hypervelocity vehicles.—(25.3 × 1.9 × 1.7).

POWER PLANTS

See also AERODYNAMICS—INTERNAL FLOW
PERFORMANCE
AIRCRAFT OPERATION
THERMODYNAMICS

A summary of preliminary investigation into the characteristics of combustion screech in ducted burners. Lewis Lab. Staff. N.A.C.A. Report 1384. 1958.
Operation of afterburners and ram-jet combustors at progressively higher fuel/air ratios has increased the occurrence and intensity of screech. Because of the destructive characteristics of screech, considerable effort has been expended in an attempt to understand and control this phenomenon. N.A.C.A. work on screech up to November 1953 is summarised.—(27.1 × 34.1.1).

Analysis of injection-velocity effects on rocket motor dynamics and stability. H. G. Hurrell. N.A.S.A. Report TR R-43. Sept. 1959.
A concept of combustion time lag that includes dependency on injection-velocity is introduced and used in the formulation of chamber transfer functions and in an analysis of low-frequency combustion instability. Theoretical frequency responses and stability boundaries are compared with those obtained when the injection velocity sensitivity is neglected. These comparisons show the injection velocity effect on the time lag to be an important consideration in the theory of chamber dynamics and combustion instability.—(27.3 × 34.1.1).

Near-field and far-field noise surveys of solid-fuel rocket engines for a range of nozzle exit pressures. W. H. Mayes et al. *N.A.S.A. T.N. D-21. Aug.* 1959.
Results are given of an experimental investigation of the sound fields generated during static firings of rocket engines having 1,500 and 5,000 lb. of thrust.—(27.3 × 5.6).

A combined water-bromotrifluoromethane crash-fire protection system for a T-56 turbopropeller engine. J. A. Campbell and A. M. Busch. N.A.S.A. T.N. D-28. Aug. 1959.
The system includes an engine fuel manifold shut-off and drain system for rapidly extinguishing the normal combustor flame, a water spray system for cooling and inerting hot engine parts likely to ignite crash-spilled fuel, and a bromotrifluoromethane system for blanketing massive metal parts that may reheat after the engine has stopped rotating.—(27.1 × 5.3).

Method for predicting off-design performance of axial-flow compressor blade rows. G. K. Serovy and E. W. Anderson. N.A.S.A. T.N. D-110. Aug. 1959.
A study was made to determine the accuracy with which axial-flow compressor-blade-row performance at off design operating conditions may be predicted by a blade element procedure.—(27.1 × 1.5.2).

Power plants for VTOL aircraft: performance calculations for several hypothetical turbofan engines. E. P. Cockshutt et al. *N.R.C. Report LR-256. July* 1959.
Calculated performance data are presented in tabular form for a wide range of altitudes, forward speeds, and engine speeds, for four hypothetical aft-turbo-fan engines, of bypass ratios 0, 1·39, 3·13, and 8·24. These performance data are used along with weight estimates to illustrate the application of turbo-fan engines to a typical VTOL mission.—(27 × 17 × 5).

Stato-reacteur et fusee: determination de la poussee en vol. (Flight measurements of ramjet and rocket thrust.) C. Bourgarel and J. Beslon. AGARD Report 196. *April* 1958.
The measurement of ram-jet rocket thrust in flight is dealt with. The three main methods discussed are the strain gauge method the thermodynamic method and the aerodynamic method. The report is in French, but an English translation of the principal parts is included.—(27.3 × 27.4).

PROPELLERS

See AERODYNAMICS—WINGS AND AEROFOILS

FATIGUE

See also MATERIALS

Fatigue loadings in flight: loads in the tailplane and fin of a Jet Provost. A. Burns. C.P. 440. 1959.
Data are presented on the fluctuating and steady loads measured during flight in the tailplane and fin of a Jet Provost. Conditions include take-off, landing, taxying, flight in turbulence, aerobatics and the use of air brakes and flaps.—(31.2.4.3 × 3.6).

Fatigue characteristics of a riveted 24S-T aluminium alloy wing. Part V. Discussion of results and conclusions. A. O. Payne et al. *A.R.L. Report SM.*268. *June* 1959.
The results of a comprehensive investigation into the fatigue characteristics of P-51D Mustang wings are discussed and conclusions concerning the fatigue behaviour of this type of structure are presented.—(31.2.4.2 × 3.6.).

Fatigue strengths of aircraft materials: axial-load fatigue tests on edge-notched sheet specimens of 2024-T3 *and* 7075-T6 *aluminum alloys and of SAE* 4130 *steel with notch radii of* 0·004 *and* 0·070 *inch. H. J. Grover* et al. *N.A.S.A. T.N. D-*111. *Sept.* 1959.
Results of axial-load fatigue tests on speciments described in the title, each having a theoretical stress concentration factor of 4·0, are presented. Tests were run at 0 and 20,000 lb./in.^{2} nominal mean stress.—(31.2.2.2.2.1×31.2.2.3.2.1).

SCIENCE—GENERAL

See AERODYNAMICS—THERMO-AERODYNAMICS

STRUCTURES

LOADS—*see also* AERODYNAMICS—LOADS
HELICOPTER AERODYNAMICS
AIRPORTS

A study of the acoustic fatigue characteristics of some flat and curved aluminum panels exposed to random and discrete noise. R. W. Hess et al. *N.A.S.A. T.N. D-*1. *Aug.* 1959.
Noise levels varied from approximately 140 to 161 decibels. Panel variables included thickness, edge conditions, curvature, and static-pressure differential. A discussion is given of siren testing as a basis for evaluating structural designs.—(33.1.2×33.2.4.5×33.2.4.8×31.2.3.1.2).

*An examination of methods of buffeting analysis based on experiments with wings of varying stiffness. A. G. Rainey and T. A. Byrdsong. N.A.S.A. T.N. D-*3. *Aug.* 1959.
A linear analysis predicts buffeting loads which are high by about 25 per cent. This difference may be associated with a relieving effect which causes flexible wings to generate smaller buffeting forces than a more rigid wing. A prediction, based on aerodynamic damping only, provided values of buffeting loads which were closer to the measured values than those predicted by the more complete analysis including both structural and aerodynamic damping.—(33.1.2×1.6.3).

*Measurements of ground-reaction forces and vertical accelerations at the center of gravity of a transport airplane taxiing over obstacles. J. M. McKay. N.A.S.A. T.N. D-*22. *Sept.* 1959.
Results are presented of the effects of ground speed and obstacle width on the vertical and rearward drag ground-reaction forces, the vertical acceleration at the centre of gravity of the aeroplane, the shock-strut displacement, and the dynamic response of the upper mass of the aeroplane structure.—(33.1.2).

THEORY AND ANALYSIS—*see also* AERODYNAMICS—
HELICOPTER AERODYNAMICS
MATERIALS
STRUCTURES—LOADS

*Deformation of thick circular plates. J. P. O. Silberstein and B. Green. A.R.L. Report SM/*265. *April* 1959.
Estimates of the deflection of the reflecting surface of a large glass reflector were required for the case in which it was supported by nine spring-loaded pads. The problem was solved approximately by finding the deflection of a thick plate supported on an annulus of the same surface area as the pads and lying symmetrically over the centroid of each.—(33.2.4.5).

*Effect of chordwise heat conduction on the torsional stiffness of a diamond-shaped wing subjected to a constant heat input. R. G. Thomson and J. L. Sanders. N.A.S.A. T.N. D-*38. *Sept.* 1959.
The reduction of the torsional stiffness of a diamond-shaped wing due to a suddenly applied constant heat input is investigated, chordwise heat conduction being considered. The dependence of torsional stiffness reduction on the heating rate and the final wing temperature is inferred from the results.—(33.2.3.2.5×33.2.3.2.9).

*Investigation of vibration characteristics of circular-arc monocoque beams. W. B. Fichter and E. E. Kordes. N.A.S.A. T.N. D-*59. *Sept.* 1959.
Experimental free-free vibration frequencies and nodal patterns of two 4 per cent thick monocoque beams, which differed only in cover-sheet thickness, are presented and comparisons are made between experimental and calculated beam frequencies. Extra modes associated with panel vibrations and cross-sectional distortions were also obtained experimentally.—(33.2.4.3.10).

*Optimum proportions of truss-core and web-core sandwich plates loaded in compression. M. S. Anderson. N.A.S.A. T.N. D-*98. *Sept.* 1959.
The proportions of truss-core and web-core sandwiches which give the minimum weight for carrying inplane compressive loads are presented. For lightly loaded sandwich plates, the truss-core sandwich is less efficient than a honeycomb sandwich, but for higher loading intensities the truss-core sandwich is more efficient. The web-core sandwich is not as efficient as either the truss-core or honeycomb sandwich.—(33.2.4.14).

High-temperature testing of aircraft structures. R. R. Heldenfels. AGARD Report 205. *Oct.* 1958.
Some of the newer equipment and techniques used for high-temperature testing of aircraft structures and structural materials are described, representative research projects are discussed and typical results are presented.—(33.2.3.0.9×33.3×21.6).

The stress distribution in a swept-back box-beam under torsional and bending loads. K. Ikeda and M. Sunakawa. Aero Res. Inst. Tokyo. Report 347. *July* 1959.
An approximate solution is presented to obtain the static stress distributions in a swept-back box-beam having asymmetrical section. The box-beam is assumed to consist of four concentrated flanges of different cross-sectional area and four thin walls of different thickness, which contact the flanges. The ribs are assumed perfectly stiff except the one nearest to the root.—(33.2.4.1×33.2.3.2).

TESTING—*see* THEORY AND ANALYSIS

THERMODYNAMICS

See also AERODYNAMICS—INTERNAL FLOW
THERMO-AERODYNAMICS
TESTING AND INSTRUMENTS
POWER PLANTS

*Approximate composition and thermodynamic properties of nonionized nitrogen-oxygen mixtures. R. A. Hord. N.A.S.A. T.N. D-*2. *Aug.* 1959.
With ionisation and nitric oxide formation neglected, analytic expressions are derived for the composition and thermodynamic properties of nitrogen-oxygen mixtures. The assumption of negligible nitric oxide is later removed and solution by iteration is used to prepare composition tables for the chemical species N, O, N_2, O_2 and NO. For densities sufficiently high for ionisation to be negligible, the results of the study are applicable to 10,000°K.—(34.1×1.2.3.1).

*Experimental investigation of air film cooling applied to an adiabatic wall by means of an axially discharging slot. S. S. Papell and A. M. Trout. N.A.S.A. T.N. D-*9. *Aug.* 1959.
An experimental investigation was made to determine the characteristics of axially discharging single-slot film cooling of an adiabatic wall exposed to a hot air stream. Basic film cooling data plots for the four slot heights investigated ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, and $\frac{1}{16}$ in.) have been presented in nondimensional form. A data correlation covering the range of effective temperature ratios from 0·1 to 1·0 was obtained using four variations of a basic correlating equation. The four equations and their limitations are included.—(34.3.4×27.3).

*Flame stability effect of gases ejected into a stream from a bluff-body flameholder. E. L. Wong. N.A.S.A. T.N. D-*128. *Aug.* 1959.
The effect of gas ejection from a bluff-body flame holder on the stability of propane-air flames was studied using the following additives: hydrogen, air, and a premixed hydrogen-air mixture.—(34.1.1).

*The characteristics of hydrogen and water as working gases for reactor-heated rocket motors. I. Sänger-Bredt. N.A.S.A. TT F-*1. *Aug.* 1959.
Hydrogen and water vapour have been investigated as to their applicability as working fluids with an energy higher by several orders of magnitude that has hitherto been available with steam boilers. Enthalpy-entropy diagrams are computed for either gas, with complete regard to dissociation, as well as ionisation, over the pressure range between 10^{+1} to 10^{-5} atm., and within the temperature range between 500 and 10,000°K. Exhaust velocities possible for water, or water vapour, are derived and compared. Heat transfer to the combustion chamber walls is examined. Three methods of heating the working fluid are investigated: fission reactor, arcs, and fusion reactors.—(34.1.1×27.3×14).

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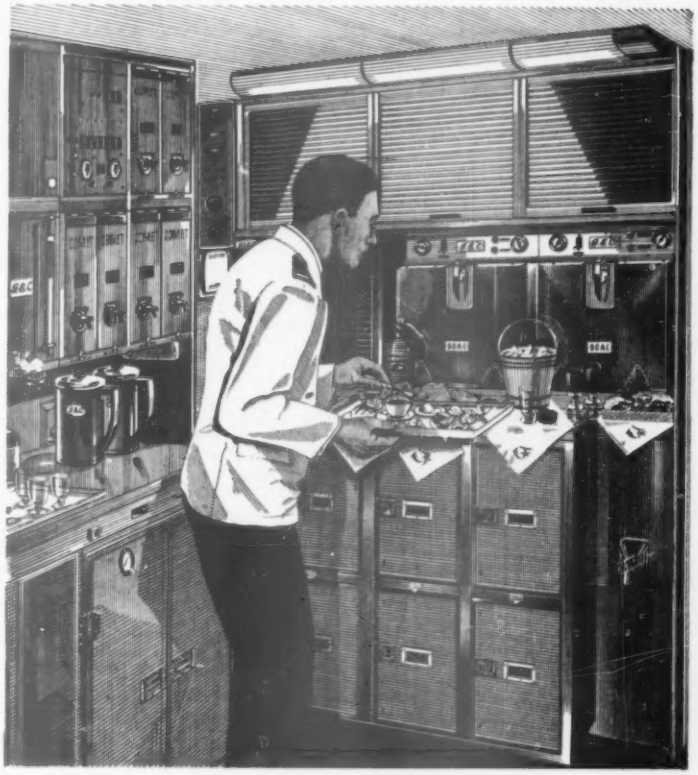

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